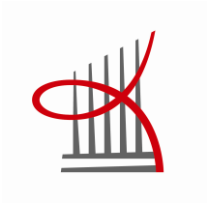


Wireless building automation in Finland

Juuse Tammilehto

Bachelor's thesis
January 2013
Degree Program of Electrical Engineering
Building Services
Tampere University of Applied Sciences

TAMPEREEN AMMATTIKORKEAKOULU
Tampere University of Applied Sciences

ABSTRACT

Tampereen ammattikorkeakoulu
Tampere University of Applied Sciences
Degree Program of Electrical Engineering
Building Services

JUUSE TAMMILEHTO
Wireless building automation in Finland

Bachelor's thesis pages 54, appendices 12 pages
January 2013

Home automation has been on markets from 1980's, before it was only available to bigger, luxury houses. Now when technology has improved and prices have been reduced, it can be installed to every house. Also wireless add-ons or even full systems, which will work completely wireless, have been released. These systems are designed to create better living environment and to be also more energy efficient.

Now even on Finnish markets you can find many different home automation systems. The ordinary system is based on power line, but the wireless in-coming system is more popular. This thesis is focused on wireless communication and different wireless technologies, which are used, such as ZigBee, Z-Wave, Bluetooth Low Energy and EnOcean.

This thesis tells you about wireless home automation. Where it can be used, what the various options cost and how ecological it is. The thesis also explores the Finnish home automation suppliers and what kind of home automation systems are available in Finland.

In addition we will model a standard single- family house and compare battery powered wireless technology, Energy Harvesting wireless technology and normal wired solution. We focus on environmental friendliness and the price of installation. This model gives you an idea, how wireless model differs from standard electricity installation and why it should be used in new buildings or renovation projects.

This thesis was entirely made on student exchange in Switzerland in Zurich University of Applied Sciences. Thanks to work guidance belongs to Prof. Dr. Marcel Meli and InES Institute of Embedded Systems department.

Key words: home automation, energy harvesting, environmental friendliness

TIIVISTELMÄ

Tampereen ammattikorkeakoulu
Sähkötekniikka
Talotekniikka

TAMMILEHTO, JUUSE:
Langaton talo-automaatio Suomessa

Opinnäytetyö 54 sivua, joista liitteitä 12 sivua
Tammikuu 2013

Taloautomaatio on ollut markkinoilla 80-luvulta alkaen, ennen se oli saatavilla vain isompiin luksustaloihin. Nykyään kun teknologia on kehittynyt ja hinnat ovat laskeneet, voidaan se asentaa jokaiseen taloon. Markkinoille on julkaistu langattomia lisäosia tai kokonaan langattomasti toimivia järjestelmiä. Automaatio järjestelmät ovat suunniteltu luomaan viihtyisämpi elinympäristö ja säästämään energiaa.

Nykyään jopa Suomen markkinoilta löytyy useiden valmistajien kotiautomaatiojärjestelmiä. Tavallinen automaatiojärjestelmä saa energiansa sähköjohtoja pitkin, mutta langattomat järjestelmät ovat yleistymässä. Tämä opinnäytetyö keskittyy langattomaan kommunikointiin ja sen eri tekniikoihin. Teknologioihin kuten ZigBee, Z-Wave, Bluetooth Low Energy ja EnOcean.

Työssä kerrotaan langattomasta taloautomaatiosta, missä sitä käytetään ja mitä vaihtoehtoja on saatavilla. Yhtenä osana lasketaan myös kuinka ekologista ja minkä hintaista se on verrattuna tavalliseen automaatioon. Työssä myös kartoitetaan Suomessa toimivia automaatiolaitteiden toimittajia ja mitä erilaisia järjestelmiä on saatavilla.

Lisäksi työssä mallinnetaan tavallinen omakotitalo ja verrataan sen valo- ja lämmitysjärjestelmien eroja rakennettaessa kolmella eri tavalla: tavallinen langallisesti rakennettu, langaton pattereilla toimiva ja langaton energiankeräysjärjestelmä. Painoarvo on ympäristöystävällisyydessä ja asennuksien hinnassa. Nämä mallit antavat esimerkin siita, miten langaton järjestelmä eroaa tavallisesta ja miksi sitä olisi hyvä käyttää uudisrakennuksissa sekä remonttikohteissa.

Opinnäytetyö on tehty kokonaan vaihto-opiskeluaikana Sveitsissä Zurich University of Applied Sciences -nimisessä yliopistossa. Kiitos työn ohjaamisesta kuuluu professori Marcel Melille ja InES Institute of Embedded Systems osastolle.

Asiasanat: taloautomaatio, energian keräys, ympäristöystävällisyys

Zürcher Hochschule für Angewandte Wissenschaften

School of Engineering

Erklärung betreffend das selbständige Verfassen einer Bachelorarbeit an der School of Engineering

Mit der Abgabe dieser Bachelorarbeit versichert der/die Studierende, dass er/sie die Arbeit selbständig und ohne fremde Hilfe verfasst hat. (Bei Gruppenarbeiten gelten die Leistungen der übrigen Gruppenmitglieder nicht als fremde Hilfe.)

Der/die unterzeichnende Studierende erklärt, dass alle zitierten Quellen (auch Internetseiten) im Text oder Anhang korrekt nachgewiesen sind, d.h. dass die Bachelorarbeit keine Plagiate enthält, also keine Teile, die teilweise oder vollständig aus einem fremden Text oder einer fremden Arbeit unter Vorgabe der eigenen Urheberschaft bzw. ohne Quellenangabe übernommen worden sind.

Bei Verfehlungen aller Art treten die Paragraphen 39 und 40 (Unredlichkeit und Verfahren bei Unredlichkeit) der ZHAW Prüfungsordnung sowie die Bestimmungen der Disziplinarmassnahmen der Hochschulordnung in Kraft.

Ort, Datum:

.....

Unterschriften:

.....

.....

.....

Das Original dieses Formulars ist bei der ZHAW-Version aller abgegebenen Bachelorarbeiten zu Beginn der Dokumentation nach dem Titelblatt mit Original-Unterschriften und -Datum (keine Kopie) einzufügen.

CONTENTS

1 INTRODUCTION 8
2 Wireless building automation generally 9
2.1 Lightning 9
2.2 HVAC 10
2.3 Security 10
3 Wireless technology 11
3.1 Battery powered technology 11
3.2 Non-battery powered technology 11
3.3 Transmission range 12
4 Wireless communication techniques 14
4.1 Bluetooth Low Energy 14
4.1.1 History and present 14
4.1.2 Technical details 15
4.1.3 Application example 16
4.2 Z-Wave 17
4.3 ZigBee 19
4.3.1 ZigBee Green Power 20
4.4 X-10 20
4.5 EnOcean 21
4.5.1 Energy harvesting with solar energy 21
4.5.2 Energy harvesting with motion energy 22
4.5.3 Energy harvesting with thermo energy 23
5 The Finnish wireless operators 25
5.1 FSM Group 25
5.2 Vaasan Sähköpalvelu Oy 25
5.3 Hedtec 26
5.4 Smart-House 26
5.5 Schneider Electric 27
5.6 Nexa Electronics 28
5.7 Other brands or companies 28
6 Ecological values of Finland 29
6.1 Energy certificate 29
6.2 Plastic 29
6.3 Copper 30
6.4 Battery 31
7 Modelling town house 33
7.1 Lightning designs 33
7.2 HVAC designs 35

8 Calculations 39
8.1 Copper 39
8.2 Plastic 40
8.2.1 Plastic from PVC pipe 41
8.3 Battery 42
8.4 The price of installation 43
8.4.1 How expensive wireless technology is 43
8.5 Life cycle assessment 45
9 DISCUSSION 47
9.1 Price 47
9.2 Environmental point of view 48
9.3 Cons about wireless automation 49
9.4 What can still be done 50
9.5 Analysing the project 50
REFERENCES 52
APPENDICES 55
Appendix 1. Typical Indoor Brightness Levels (Lux) 55
Appendix 2. Energy certificate 56
Appendix 3. Risk Analysis 57
Appendix 4. Perhehelmi plain layout ground floor 58
Appendix 5. Perhehelmi plain layout 2nd floor 59
Appendix 6. Perhehelmi standard lightning layout 1st floor 60
Appendix 8. Perhehelmi wireless lightning layout 1st floor 62
Appendix 9. Perhehelmi wireless lightning layout 2nd floor 63
Appendix 10. Perhehelmi heating layout 1st floor 64
Appendix 11. Perhehelmi heating layout 2nd floor 65
Appendix 12. Project plan 66

ABBREVIATIONS AND TERMS

EnOcean	EnOcean is a company, which offers wireless technology to companies worldwide. It is based on energy harvesting technology.
Z-Wave	Z-Wave is a company offering wireless technology, which is designed to single family houses.
Zigbee	Zigbee is a worldwide standard. which is offering technology to various companies. Zigbee devices can be used in small buildings and also in bigger facilities such as office buildings.
X-10	X-10 is an old wireless standard, originally from United States, and now available also in Europe.
HVAC	Heating, ventilation and air conditioning
LED	Light-emitting diode
Mesh Network	is a type of networking, in which each node must not only capture and disseminate its own data, but also serve as a relay for other nodes, that is, it must collaborate to propagate the data in the network.
Node	Nodes communicate with each other and use some sort of ad-hoc networking protocol to route messages amongst themselves without the need for a traditional, hierarchical routing model.
BACnet	Is a communications protocol for building automation and control networks.
AES	The Advanced Encryption Standard (AES) is a specification for the encryption of electronic data.
EH	Energy harvesting
ICT	Information and communications technology
RF	Radio frequency
Bluetooth SIG	The Bluetooth Special Interest Group (SIG) is a privately held, not-for-profit trade association founded in 1998 with more than 17,000 member companies today.

1 INTRODUCTION

Home automation is part of building automation. Normal building automation is usually used for office and public buildings. With this specific way you can control lightning, security and HVAC, for example. The main purposes of automation are energy saving and comfort improvement. Energy saving can be one third or even more of energy consumption compared to ordinary building without any automation.

Due to new construction and stricter rules on environmental emissions, home automation has become more popular. Energy consumption plays fairly large role, when you buy a new house. From 2009 in Finland any new residential real estate has Energy Certificate, which tells, how energy efficient the house is. Old single-family houses consume much more energy compared to newer ones.

Nowadays it is popular to renovate old house to look like modern. At the same time, when a house is renovated, also electricity is usually updated. With wireless components you don't have to install cables inside structures, and that saves time and money. Some manufacturer devices are easy to install, and you don't have to buy the full system at once. You can purchase lightning devices first, and after that expand your system with security or HVAC.

Wireless systems have been quite expensive before, so that is why it has not been popular. Now when more different products are available on markets in Finland, price of the whole system is reduced to an acceptable level and more wireless devices are used.

This work tells you differences of various systems on the market. The most common installation target is a standard house, so we model average single-family house and show, what kind of solutions are available. We compare environmental friendliness and prices of installation between wireless and wired components. We will tell also, what kind of technology is used in wireless communication, and at which point Finland is at the moment with the wireless home automation.

2 Wireless building automation generally

Wireless automation has become nowadays more popular. Usually wireless components have been used as a part of larger automation system. However, now there are systems that can operate fully without wires. Roughly they can be categorised in two different groups: battery powered and non-battery powered devices.

Wireless devices can be used in various different household or public properties. Some of them fit better in public properties, because of the longer transmission range of data, while others are designed just for a household use. Most common type of use is lightning, HVAC and security. With modern systems your home can be controlled with computer or even by smart phone. Now we will concentrate to the most common applications.

2.1 Lightning

Light designing has a big role on energy-efficient manner. Electric designers try to create a user-friendly environment with lightning. It is not such an easy task, if you do not want to spend much money for that. Good variable lightning in a household or office environment needs always building automation. With that you can control light intensity the way you want, and if it has been sensibly designed, it will control by itself depending on how much natural light is available.

The lightning might also relate to security. With automation you can keep few lights on in the office to make it look like somebody is in there, commonly used in night time to keep robbers away. Very common is also to make different light scenes to different situations for e.g. movie, cleaning and reading.

To be more energy efficient it is recommended to use as much natural light as possible. Natural light does not consume energy like artificial lightning does. Now when light bulbs are banned from Europe (September 2012) excluding indicator lamps, you have to use LED, fluorescence or halogen lights. (EU Dir. 244/2009). These lamp types consume less energy than light bulbs, but still lots of energy or lamps can be saved with right solutions.

2.2 HVAC

HVAC is the most effective way to save energy. Heating in Finland in winter time consumes much more energy compared to the Middle Europe, that is why it is important to produce only necessary amount of heating. For e.g. with wireless window sensors heating system can notice, that it is useless to warm room if the window is open.

When you have good HVAC automation system you will not loose energy to air, meaning that ventilation is also optimised correctly in order to be energy efficient. If you are not at home or at office, it is useless to have air conditioning running there with full power. Home automation is usually equipped with different scenes. “Home” or “away” scene is much-used feature, which allows you to adjust for e.g. air condition unit to half power, when you are not at home.

With the complete HVAC system you can control different rooms separately. In common room area or kitchen temperature can be set to 22℃ and in bedroom to 18℃ to get better sleeping quality. When each window and radiator have own wireless device, it is easy to control energy-efficiency of the system.

2.3 Security

Security is also one of the key options, which can be controlled by automation. With wireless window sensors you can see, if a burglar breaks a window and tries to come in. Almost all different sensors can be included to one big security system. If you leave home in a hurry and you don’t remember, did you lock the door, it is possible to do it with you smart phone for e.g.

Even motion sensor can trick alarm system. If you have set the system to “away from home” and motion sensor recognises movement in apartment it might turn on all the lights, start recording with IP-camera and make an alert to security-company.

3 Wireless technology

Wireless automation can be divided into two categories: battery powered and non-battery powered function. Battery powered is more popular at this time and it has been longer on the market. Non-battery powered application get its energy with different techniques for e.g. solar, kinetic or thermal energy.

There are many manufacturers in this field and many different systems. That is why it is important to know, what you buy. Usually data travels with radio waves. In Europe and U.S there are different regulations for wireless data transfer. That is why all products will not work in both continents. Some manufacturers offer two different systems, one for the continent of United States and another for Europe and the rest of the world.

3.1 Battery powered technology

There are many different types of battery powered data transferring technologies in these days. Some of them have been on market since 1980´s such as X-10, designed on the US continent. Some of the technologies are standardised and you can mix devices from different manufacturers of same standard.

The basic rule is, that every RF signal in a household can be operated with battery, but without battery it is more complicated. It depends on energy consumption. Some technologies consume too much energy to transmit the message, so they could not be operated with solar energy for e.g. As available options remain then to get the power from battery or from AC mains.

3.2 Non-battery powered technology

Non-battery powered technology means, that energy to transmit signal has to be produced from the surrounding nature. This method, referred to as energy harvesting, is very ecological, because these products almost work forever without any maintenance. At this moment company called EnOcean is the most famous in this field.

EnOcean technology is entirely based on the energy harvesting. It is a process, where energy is derived from external sources, namely solar power, thermal power and kinetic energy. This energy is captured and stored for use in small, wireless, autonomous devices like those used in wireless sensor networks. Energy harvesting devices convert ambient energy into electrical energy. Energy can be stored using a small capacitor instead of needing batteries, which provide a constant flow of power. Devices that work without battery have been designed so, that they will not use much energy. (EnOcean whitepaper)

3.3 Transmission range

As the radio signals are electromagnetic waves, the signal is damped on its way from the sender to the receiver. That is to say, the electrical as well as the magnetic field strength is removed inversely proportional to the square of the distance between sender and receiver ($E,H \sim 1/r^2$). (Deterioration in signal Peha)

Beside these natural transmission range limits, there are further interferences that have to be considered. These electromagnetic signals do not penetrate metallic parts for e.g. reinforced concrete walls usually contain metal. To get idea how good radio signals penetrate different material you can see on TABLE 1. (Transmission range Peha)

Material	**Penetration (%)**
Wood, gypsum, glass uncoated	90-100
Brick, pressboard	65-95
Reinforced concrete	10-90
Metal, aluminium pasting	0-10

TABLE 1 Penetration of radio signals (Peha white paper).

To get an idea what those numbers mean Peha has made an example, where you can see, what might be the typical transmission range on different situations.
Radio path range/-penetration:
Visual contacts: Typically 30m range in passages, corridors, up to 100m in halls
Gypsum walls/wood: Typically 30m range through max. 5 walls
Brick wall/Gas concrete: Typically 20m range through max. 3 walls
Reinforced concrete/-ceilings: Typically 10m range through max. 1 ceiling

Moreover, the angle how signal arrives at the wall is great importance. If possible, the signals should run vertically through the walling. Other interference sources that operate with high-frequency signals for e.g. computer might also make interference to radio signal. The minimum mounting distance to such devices should be more than 0.5 m. (Transmission range Peha)

4 Wireless communication techniques

When it comes to wireless communication, there are as many techniques as device manufacturers. Bigger companies usually use standardised radio frequency data transfer such as Z-Wave or ZigBee, when smaller producers just use their own technology. That means, that if any of your devices breaks down and it is not standardised, you have to buy the same device again from the same manufacturer.

These most common wireless technologies have their own Alliances, where different companies can join. Good thing with these wireless Alliances is, that you can mix you your devices with products of other manufacturers. From EnOcean for e.g. you can find 938 devices, which match in Europe with products of 67 different manufacturers (EnO-cen Alliance December 2012).

4.1 Bluetooth Low Energy

Bluetooth low energy (BLE) is a feature of Bluetooth 4.0 wireless radio technology, aimed at new, principally low-power and low-latency, applications for wireless devices. This facilitates a wide range of applications and smaller form factor devices in the healthcare, fitness, security and home entertainment industries. (Bluetooth Low Energy Wikipedia)

4.1.1 History and present

History of Bluetooth Low Energy began in 2001. When Nokia researchers noticed that there was various scenarios contemporary wireless technologies did not address. The Nokia Research Centre started developing a wireless technology, adapted from the Bluetooth standard. In October 2006 technology was released to public with brand name Wibree. After negotiations with Bluetooth SIG members in June 2007, an agreement was reached to include Wibree in future Bluetooth specification as a Bluetooth ultra-low-power technology, now known as Bluetooth Low Energy technology. (Bluetooth Low Energy Wikipedia)

Integration of BLE technology with the Core Specification was completed in early 2010. The first device to get the Bluetooth v4.0 spec was the iPhone 4S, which came out in October 2011. Some other mobile phones, which support Bluetooth 4.0:

- Apple iPhone 5
- Samsung Galaxy S III
- Motorola Droid RAZR
- HTC One S

Bluetooth Low Energy is also available on Windows 8 PC, Apple iPad, iPod and Mac Book Pro. However, Nokia which was one of the developing companies of this standard has not any smart phone, which supports BLE on the market (November 2012). (Bluetooth Smart Devices Bluetooth.com) (Phone technical data Nokia)

4.1.2 Technical details

Bluetooth low energy technology operates in the same spectrum range (2402-2480 MHz) as Classic Bluetooth technology, but uses a different set of channels. Instead of Bluetooth technology's 79 1 MHz wide channels, Bluetooth low energy technology has 40 2 MHz wide channels. (Bluetooth Low Energy Wikipedia)

Bluetooth low energy technology is designed with two equally important implementation alternatives: single-mode and dual-mode. Small devices like tokens, watches and sports sensors based on a single-mode Bluetooth low energy implementation will enjoy the low-power consumption advantages enabled for highly integrated and compact devices. In dual-mode implementations Bluetooth low energy functionality is integrated into Classic Bluetooth circuitry. Main differences can be found on TABLE 2. (Bluetooth Low Energy Wikipedia)

Technical Specification	Classic Bluetooth technology	Bluetooth low energy technology
Distance/Range	100 m (330 ft)	50 m (160 ft)
Over the air data rate	1-3 Mbit/s	1 Mbit/s
Application throughput	0.7-2.1 Mbit/s	0.26 Mbit/s
Security	56/128-bit and application layer user defined	128-bit AES with Counter Mode CBC-MAC and application layer user defined
Latency (from a non connected state)	Typically 100 ms	6 ms
Total time to send data (det.battery life)	100 ms	6 ms <3 ms
Voice capable	Yes	No
Network topology	Scatternet	Star-bus
Power consumption	1 as the reference	0.01 to 0.5 (depending on use case)
Peak current consumption	<30 mA	<20 mA
Primary use cases	Mobile phones, gaming, headsets, stereo audio streaming, automotive, PCs, security, proximity, healthcare, sports & fitness, etc.	Mobile phones, gaming, PCs, watches, sports and fitness, healthcare, security & proximity, automotive, home electronics, automation, Industrial, etc.

TABLE 2 Differences between Bluetooth and Bluetooth low energy.

(http://en.wikipedia.org/wiki/Bluetooth_low_energy)

4.1.3 Application example

The research team in Zürich University of Applied Sciences at InES (Institute of Embedded Systems) developed solar powered BLE ambient sensor. This wireless sensor can operate with sun or artificial light. As soon as the energy is available temperature and relative humidity are measured. The data can be sent to smart phone that supports Bluetooth Low Energy, in this case shown with Apple IPhone 4S, PICTURE 1. The system runs with only about 100 µJ energy, which means that solar cell do not have to be big and this allows companies to make the sensor small and low cost.

PICTURE 1 Solar powered BLE ambient sensor.
(http://www.ines.zhaw.ch)

4.2 Z-Wave

Z-Wave is a standard, which different product manufactures can use. The Z-Wave Alliance was established in early 2005 by a group of leading home control product manufacturers, each dissatisfied with the technological fragmentation that was strangling the promise of the then-nascent home controls industry. Their goal was to move that industry from an uncertain, unspecified future to a practical and widespread reality. (Z-Wave alliance)

Z-Wave is currently supported by over 160 manufacturers worldwide and there are over 700 different products on offer. A Z-Wave network can consist of up to 232 nodes (devices), but if you add a gateway, multiple Z-Wave networks can be combined. That is not usually necessary in normal single-family houses. Typical wireless range is 25 m

inside and up to 100 m outside buildings. It depends on walls and materials used on building. Z-Wave is designed to single-family houses, but they can be installed also slightly bigger houses. (Z-Wave Alliance)

Technology is based on radio frequency data transferring of 868,42 MHz in Europe, 908.42 MHz (United States), 919.82 MHz (Hong Kong) and 921.42 MHz (Australian/New Zealand). (Z-Wave Wikipedia)

Z-Wave uses a source-routed mesh network topology and has one primary controller and zero or more secondary controllers, which control routing and security. Devices can communicate to one another by using intermediate nodes to actively route around and circumvent household obstacles or radio dead spots that might occur. A message from node A to node C can be successfully delivered even if the two nodes are not within range, providing that a third node B can communicate with nodes A and C. If the preferred route is unavailable, the message originator will attempt other routes until a path is found to the "C" node. From (PICTURE 2) you can see the idea of mesh network topology. (Z-Wave Wikipedia)

PICTURE 2. Z-Wave mesh network.
(http://www.zwavealliance.org)

4.3 ZigBee

ZigBee is a standard technology that operates on 2.4 MHz frequency band according to IEEE 802.15.4. ZigBee Alliance was, founded in 2002 and it is a non-profit organisation, to which companies from different fields can join. There are different standards for e.g. ZigBee Remote Control, ZigBee Smart Energy, ZigBee Retail Services, ZigBee Building Automation. (ZigBee Alliance)

With ZigBee you can make an enormous automation system, because it allows more than 64000 nodes (devices) in one network. Wireless range is up to 70m indoors and 400m outdoors. You can also connect to BACnet automation system with wireless devices. It is secure to use encryption what ZigBee uses, AES 128 encryption keys and device authentication. (ZigBee Alliance)

The communication style of ZigBee is based on three different device types: coordinator, router and end device. Coordinators control the formation and security of networks. Routers extend the range of networks. End devices perform specific sensing or control functions. Manufacturers often create devices, which perform multiple functions, for example a device controls a light fixture and also routes messages to the rest of the network. (ZigBee Alliance)

The (PICTURE 3) illustrates an example ZigBee topology, which includes one coordinator, five routing devices and two end devices creating a control network. An example network in a smart home, the coordinator may be a Home Theatre control system with advanced support for lighting and security. Devices such as light fixtures, thermostats and air conditioners could be configured as routing devices. Simple devices such as light switches and security sensors could be end devices. (ZigBee Alliance)

PICTURE 3 ZigBee communication topology.
(http://www.zigBee.org)

4.3.1 ZigBee Green Power

ZigBee has announced (19.12.2012) a new technology, which will use energy harvesting method. This green power is the more eco-friendly option than the normal battery powered. ZigBee Green Power can be connected secure to the ZigBee PRO networks. At first Green Power will be integrated with ZigBee Building Automation™ and ZigBee Home Automation™. (ZigBee Alliance Green Power White paper)

4.4 X-10

X-10 is an international open industry standard for communication among electronic devices used for home automation. It has devices with power line and devices that work wireless. X-10 was developed in 1975. Nevertheless the European model came out in 2001, 230VAC 50 Hz and it is called Xanura. (X-10 Wikipedia)

X-10 uses radio frequency of 310 MHz in U.S and 433 MHz in Europe. The standard X-10 power line and RF protocols lack support for encryption, and can only add 256 devices. Unfiltered power line signals from close neighbours using the same X-10 device addresses may interfere with each other. Interfering RF wireless signals may simi-

larly be received, with it being easy for anyone nearby with an X-10 RF remote to willingly or unwillingly cause mayhem if an RF to power line device is being used on a premises. (X-10 Wikipedia)

4.5 EnOcean

EnOcean is a company, which is based on extra low energy consumption and for this reason it is using energy harvesting technology. It has an Alliance, to which different manufacturers can join and then use this same RF technique. There are so far three different ways to produce enough energy to send and receive data: Solar, Motion and Thermal.

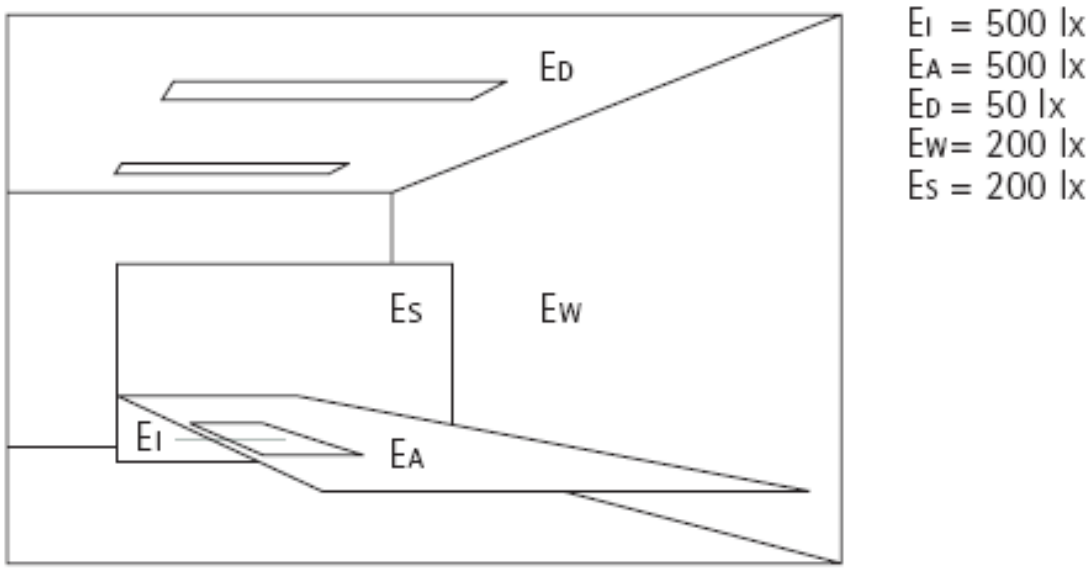
4.5.1 Energy harvesting with solar energy

EnOcean is currently offering two types of indoor solar cells: ECS 300 and ECS 310. The smaller ECS 300 is intended to be used in unidirectional sensor applications. ECS 310 is designed for use in bi-directional applications. Both of them are designed for use with EnOcean sensor modules STM 300/STM 300C. (EnOcean whitepaper)

Brightness is a term, which describes how intense a light source is perceived by the human eye. Brightness is measured in units called LUX (lx). During daytime, the light indoors will be a mixture of daylight and artificial lamplight varying throughout the day, weather and season. The amount of available sunlight is minimal in mid-winter. (EnOcean whitepaper)

In order to get these solar powered sensors to work they need to have enough light. The value of the product between illuminance (lux) and time (hours), known as lux hours (lxh) can be roughly taken as a constant at illuminations over 130 lx. For e.g. 200 lx illumination for 2 hours are equivalent to 400 lx illumination for 1 hour (400 lxh). (EnOcean whitepaper)

In PICTURE 4 you can see examples of brightness levels at different spots in a typical office room. Defined lightning conditions are made to help get the idea of illumination on different environments. From Appendix 1 you can see reference values.

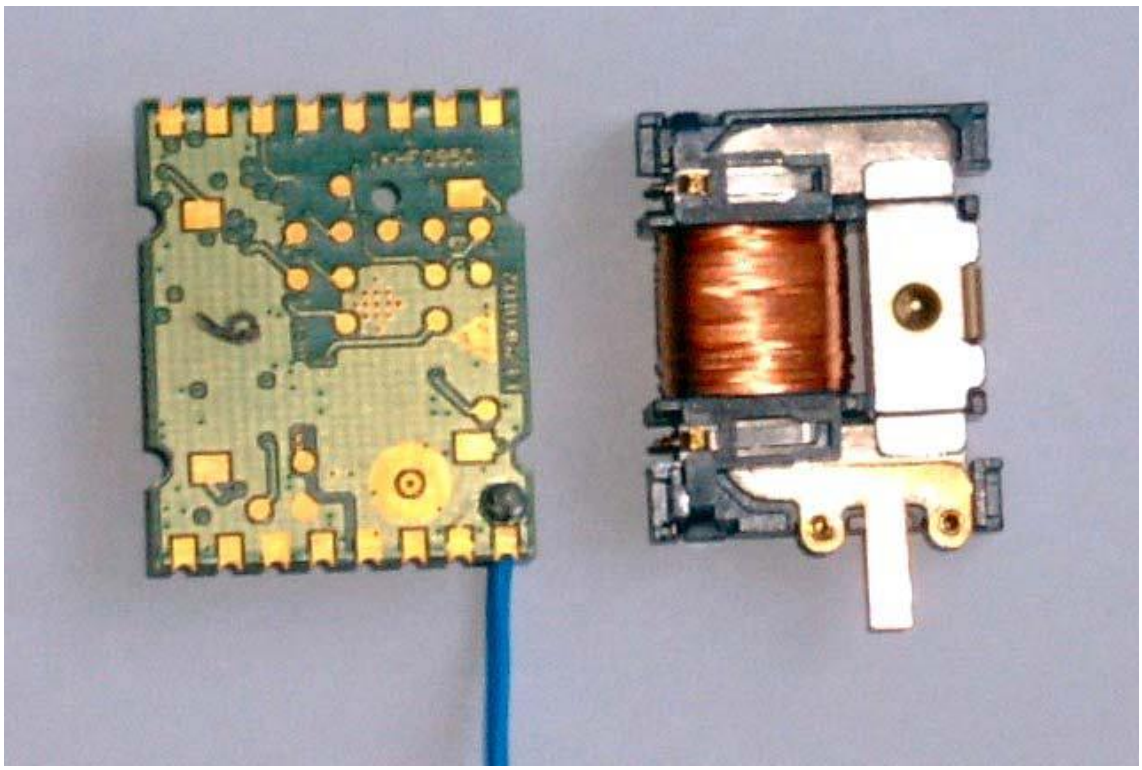


PICTURE 4 Example of brightness levels in office room.
(http://www.enocean.com)

4.5.2 Energy harvesting with motion energy

Motion energy harvesting is based on the Piezo effect. Part of the mechanical energy is converted into electric energy, enough to transmit a switching signal over a distance of a few hundred meters for instance. Then the energy is used up, and the spring has to operate again for the next signal. (EnOcean White paper)

ECO 200 is electrodynamic energy converter for small and flat designs. Usual target applications are window and door sensors or wireless key card switches. The energy module ECO 200 is an energy converter for linear motion. It can be used to power the PTM 330 radio module or derivates. The energy output at every actuation of the spring is sufficient to transmit 3 sub-telegrams with a PTM 330 module. Possible applications are miniaturized switches and sensors in building technology and industrial automation. PICTURE 5 shows PTM 330 wireless switch module at left and energy harvester ECO 200 at right. (EnOcean White paper)



PICTURE 5 EnOcean wireless switch and motion energy harvester.
(http://www.enocean.com)

4.5.3 Energy harvesting with thermo energy

Thermo energy harvesting is based on Peltier effect. EH is possible with standard Peltier element in combination with EnOcean ultra low power DC/DC converter. Peltier element, which collets energy from surrounding air or surface, can operate with small temperature difference. Operation starts at 20 mV relating to 2 Kelvin temperature difference. (EnOcean white paper)

The ECT 310 DC/DC converter enables energy harvesting wireless modules to use heat as their power source. Electricity is produced from heat emitted from machinery parts, radiators or even the human body, for instance. This marks another important step in the continuing development of the company's energy harvesting technology for building and industrial automation. (EnOcean white paper)

A typical thermo-driven sensor consists of a sensor element, a small Peltier element, the ECT 310 DC/DC converter and an EnOcean STM 300 or STM 312 radio module.

When the STM 300 can not storage energy, the STM 312 module already has an energy storage on board. (EnOcean white paper)

From FIGURE 1 you find differences between Peltier element and heatsink. An EnOcean radio module, which wakes up every 2 min. to transmit telegram needs ~5 µW on average only. (EnOcean white paper)

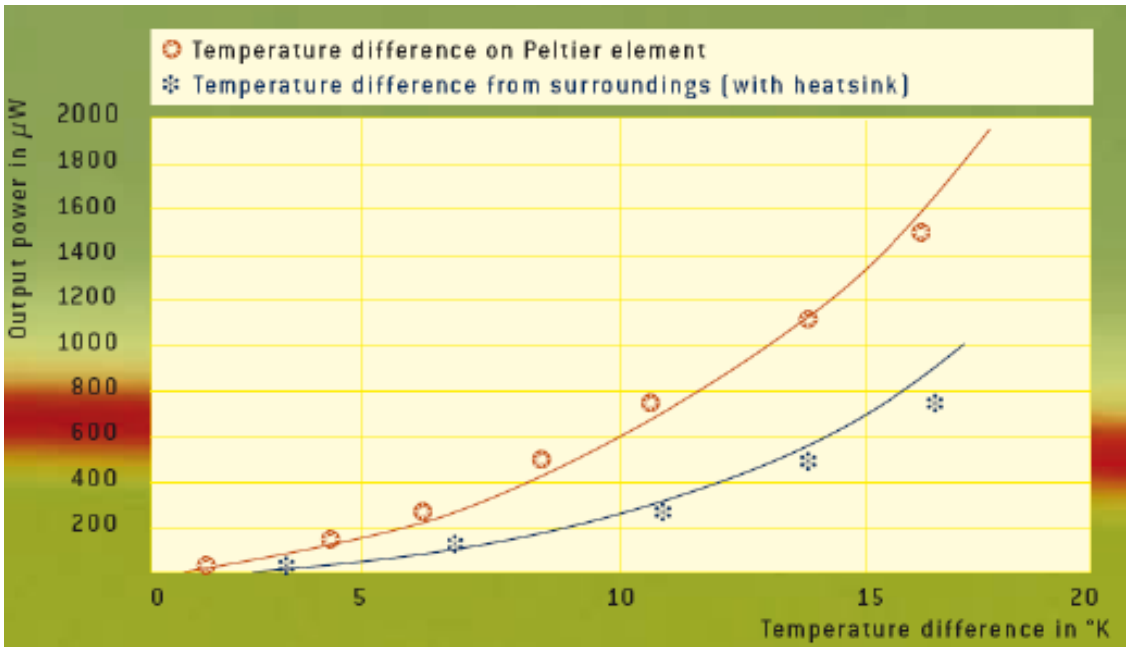


FIGURE 1 Energy Calculation Example.
(http://www.enocean.com)

Output power from ECT 310 in combination with Peltier element TEC2L-15-15-15-5.6:
Red = temp. diff. @ Peltier, blue = temp. diff. against ambient temp. (via heat sink).
Start up at 2K, ~100 µW of energy is already produced for a temp. diff. of 7 K. (EnOcean white paper)

Key Applications for this element is Sensors for Building and Industrial automation and Medical (heat cost allocator, temperature sensor, process control, preventive maintenance, etc.) Also Actuators for Building and Industrial automation (water valve, air flap, other mech. dev.) (EnOcean white paper)

5 The Finnish wireless operators

In Finland wireless automation is not that common as in other Northern countries or in Europe. According to the questionnaires, which I sent to the Finnish electricity companies, specializing in wireless technology. Entertainment electronics and mobile phones are on quite high level, but they have not reached home automation yet.

Typical installation location are so-called luxury houses. They are usually slightly bigger than an average single–family house. Ordinary size of a luxury house is 200 m2 plus, and they are equipped with high quality materials. Following companies work in Finland, specializing in wireless home automation:

5.1 FSM Group

FSM Group Oy was established in 1980´s, World Comp Oy was founded in 1985 and FSM Oy Fonel Security Marketing in 1991. Both companies grew in 1990´s to leading importers of Electrical Safety Technology. These companies merged in 2003.

FSM Group has grown to be the leading wholesaler of Safety Technology in Finland. Company turnover is currently approximately 8 M € and it employs 19 employees (2011). Headquarters are located in Vantaa and a subdivision in Ylöjärvi.

Now FSM Group is offering home automation system called Citygrow. Citygrow is designed for home automation and it is based on ZigBee standard. This new automation system is just launched in Finland, but these devices have been installed in Asian and European countries such as Germany and France. (FSM Group)

5.2 Vaasan Sähköpalvelu Oy

Vaasan Sähköpalvelu Oy is specialized designing, sales and installation of electric-, ICT-, building automation- and safety products. It is founded in 1991 and it employs about 25 employees. Turnover was 2.6 M€ in 2010.

Vaasan Sähköpalvelu is located in western Finland city called Vaasa and it operates mostly there. They offer almost everything related to electricity including accessory sales, designing, installation, maintenance/repair and subcontracting. They offer also sales and assembly of KNX bus technology and EnOcean devices. (Company profile Vaasan Sähköpalvelu)

5.3 Hedtec

Hedtec is importer and distributor of electrically operated products in Finland. It is part of Finish Hedengren Group, which is founded in 1918. Hedtec employs 53 employees and achieved turnover of 32 M€ (2011). Hedtec is located in Southern Finland in Helsinki. (Company profile, Hedgren)

Hedtec imports home automation products, manufactured by German manufacturer called Peha. Peha offers radio control system technology, which operate wireless and they are based on EnOcean technology. They manufacture over 100 different wireless EnOcean based devices. These devices are called Easyclick, and they are receiving their energy from mechanical energy. (Company information Hedtec)

5.4 Smart-House

Smart-House is a brand of Carlo Gavazzi Group, the Italian internationally active electronics group, which is designing, manufacturing and marketing electronic equipment, and was founded in 1931. (Company information Carlo Gavazzi)

25 Contractors offer this Smart- House system in Finland. However to Finland have been installed only about 40 systems, compared to other Nordic countries (10000) and worldwide (100000) systems. The most common installation destination is slightly bigger than an average single-family home, usually between 140-350 m2. (Email Joonas Silaste)

Smart-House wireless devices communicate on 868 MHz frequency and they don’t rely on any standard. Central unit is connected vie Ethernet or WLAN, which allow commu-

nication on every device in system. With every gadget (PC, Android phone/pad, IPhone etc.) which has internet connection, it is possible to control this system. With additional Smart-House controller BH8-CTRLX-230 system can be operated also with GSM-phone via SMS messages. (Data sheet Smart-House)

Pros and cons about Smart-House system. Wireless switch/motion detectors are good in many places. In Stone and log house you save money on labour costs. Remote controls and key chain buttons are useful, but mainly they are only a comfort factor. All devices are easy to program, they are installed in the same way. Wireless components are "paired" with central unit by pushing programming button on device and central unit. (Email Joonas Silaste)

According to survey about Carlo Gavazzi wired installation is more common in Finland. With wired components you can use LCD displays and signal lights. Prospects look good on wireless markets, when other options are coming to markets but basic installation will remain wired. (Email Joonas Silaste)

5.5 Schneider Electric

170 years of history. From 1836 until today Schneider Electric has transformed itself into the global specialist of energy management. Initially this company was not in electrical industry, but it was focused on iron and steel production. In early 21st century Schneider became specialist in energy management with their products such as TAC, Clipsal and Xantrex. From 2010 Schneider is focusing more on Smart Grid. (Company introduction Schneider Electric)

Schneider calls their wireless control system as Connect. The Connect is based on Z-wave technical standard, where devices transfer data with RF. Couple of thousand systems have been sold to Finland. Conventional installation target is room-specific renewal or need for additional control. Some new single-family houses have been fully implemented with these wireless devices, but this is rare. (Email Kalevi Härkönen)

5.6 Nexa Electronics

Nexa is a Swedish company, which specializes in wireless controlling. It manufactures two types of radio communication systems: SystemNexa and Nexa Professional. SystemNexa is based on 433.92 MHz, while the Professional version is based on 868 MHz frequency. Nexa Pro is aimed primarily to user with higher demand on appearance and compatibility with existing framework in their homes. (Product info Nexa)

They have Europe's widest range of remote controls for consumers. In Finland you can find many retailers on internet stores, such as verkkokauppa.com, tekniikkakauppa.fi and data-systems.fi. For installing some of Nexa products you do not need even an electrician, and they are quite cheap in comparison to other manufacturers' products, for this reason they are so popular in Europe.

Nexa offers over 30 different devices from light switches to wireless motion sensors. In December 2012 Nexa released gateway and with that you can control your system on computer, iPhone or Android phone. (White paper Nexa)

5.7 Other brands or companies

There is also one interesting company, which operates in the field of home automation called Eldistribution. They sell system called Control 4. It works in ZigBee interface and it is specialized in entertainment electronics. You can fully operate these devices with PC, IPhone or IPad for e.g. also another company called Älysähkö sells this Control 4 system. Unfortunately I could not get in contact with them.

There are small manufacturers on the market, which sell wireless devices. Only diverse home automation systems can not be built with them, because these products are intended to simple installation.

6 Ecological values of Finland

What concerns ecology, Finland is well on track and environmental issues are efficiently implied. The following factors were included in this project. The values used in this case are universal European ecological values of copper, plastic and battery.

6.1 Energy certificate

Since 01.01.2009 Energy Certificate is required from new properties, when property or it's facilities is offered for rent or for selling purposes. Certificate is not required from industrial buildings or holiday homes, which are used for up to 4 months a year. Energy Certificate is classified on the scale A-G. Least energy consuming property is classified as A and the most energy consuming as G. (Energy Certificate Ympäristö)

Energy Certificate of single-family houses is always made by calculating. To get the total amount of a property's energy consumption you need to add these three things:

- Room space heating energy
- Domestic hot water heating energy (based on the number of bedrooms)
- Equipment electricity use (table value of the gross area)

The classification of Energy efficiency is determined on the basis of energy efficiency number, which is obtained by dividing the total gross energy consumption in the gross field. A single-family home Energy Certificate is valid for 10 years. Appendix 2 shows an example of an Energy Certificate. (Energy Certificate and statement Energiatehokaskoti)

6.2 Plastic

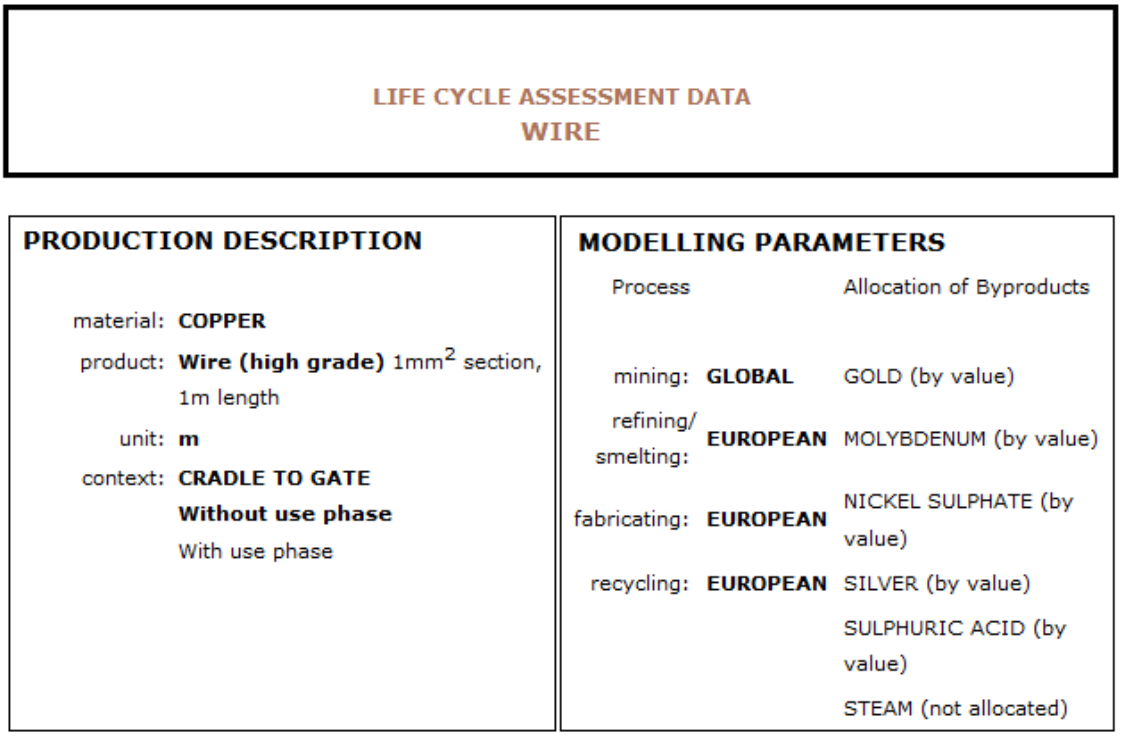
In the following case use of plastic was calculated from the copper wire insulations and the cable ways used PVC pipe. The exact CO_2 emission to plastic is from PlasticEurope. Injection moulded PVC produces 6.0 kg CO_2/kg of plastic. (Plastic info PlasticEurope)

6.3 Copper

Copper price varies all the time, but the truth is, that more copper is needed everywhere and price of copper is gradually going up. On 5.12 2012 the price of copper ton was 8022 USD. (Copper price Metalprices)

The increase of copper price has been noticed also by thieves. Copper stealing has come more common in Finland, too. In July 2012 Finnish Police had over 20 metal theft cases, increase from previous year approximately 15 %. Finnish Customs seized often stolen metal, which was on it's way to Estonia. (Metal theft Helsinginuutiset)

The biggest savings with wireless installations come from lack of wires and installation time. The following model plan of a house electrical system will show, how many meters of wires were saved and the saved CO_2 emissions can be calculated. PICTURE 6 shows facts on 1 mm^2 wire and with that we can calculate the needed result.



LIFE CYCLE ASSESSMENT DATA
WIRE

PRODUCTION DESCRIPTION

material: **COPPER**
product: **Wire (high grade)** 1mm^2 section, 1m length
unit: **m**
context: **CRADLE TO GATE**
Without use phase
With use phase

MODELLING PARAMETERS

Process		Allocation of Byproducts
mining:	**GLOBAL**	GOLD (by value)
refining/ smelting:	**EUROPEAN**	MOLYBDENUM (by value)
fabricating:	**EUROPEAN**	NICKEL SULPHATE (by value)
recycling:	**EUROPEAN**	SILVER (by value)
		SULPHURIC ACID (by value)
		STEAM (not allocated)

RESULTS

Primary Energy Consumption	0,000472	GJ/m
Global Warming Potential	0,0378	kg CO_2-equiv/m
Acidification Potential	0,00027	kg SO_2-equiv/m
Eutrophication Potential	0,000016	kg PO_4-equiv/m
Ozone Depletion Potential	1,46 E-09	kg R11-equiv/m
Photochemical Ozone Creation Potential	0,000016	kg Ethene-equiv/m

last updated January 2012

PICTURE 6 Copper wire life cycle assessment (http://www.kupfer-institut.de/lifecycle/)

6.4 Battery

Batteries of different manufacturers vary, but usually on low energy devices such as light switch they use small Lithium-ion coin battery. In thermostats, where you need more power to measure and send the signal to receiver, you use bigger and more powerful AAA batteries.

Battery manufacturer called Varta has calculated the carbon footprint of standard AA alkaline-manganese battery and discovered, that the 90% of all greenhouse gas emissions is caused by production and transport of raw materials. In total, an AA battery over its entire life cycle generates approximately the same greenhouse gas emissions as a conventional small car result of the combustion process for 1 km. (Carbon footprint of AA battery Varta/Aalen University)

Schneider uses in their Connect series li-ion battery model CR 2450. Battery manufacturer called Energizer show, that weight of CR 2450 is 6.8g. The research done by Argonne shows, that average CO_2 emission of li-ion batteries is 12.5 kg/kg. (Battery facts Energizer, Argonne)

There are few options on this AAA battery model, Duracel for e.g. have NiMH (Nickel-Metal Hydride) and Alkaline-Manganese Dioxide batteries. They have three different rechargeable NiMH and four non chargeable batteries. The weight varies from 6 g to 12.8 g depending on the model. In this model we choose NiMH option, which average CO_2 emission is 13.6 kg/kg. (Battery facts Duracell, Argonne)

7 Modelling town house

The model of a house, which I chose, is an ordinary single-family house. Wireless devices are usually used in them. The base of my model is from Finnish house manufacturer called Helmitalo. This house model is the largest of their manufactured models with 197 m^2 gross floor area and 173 m^2 floor space (December 2012). The house is 1.5 floors high, which means that the upper floor is not as big as the ground floor. The plain layout of the house with little interior design can be found on appendixes 4 and 5.

The program, which I used for designing the electrical plan, was CADS Planner. CADS Planner is a product of a Finnish company called Kymdata Oy. With this program you can calculate the amount of wires in the house and how much and what kind of objects you use.

Designing house electricity with wireless component and standard wired way does not differ much. However, when we look more closely these two different electrical plans, we find various differences. Electrical designing is based on interior design, which Helmitalo had on their layout Appendixes 4 and 5.

7.1 Lightning designs

When you design lightning, it is important to think the way the people would like to control the lightning in the house. It has to be comfortable to live with and it has to be adjustable according to the situation. Energy efficiency is in a big role nowadays so you must think about this point of view also.

To create a perfect lightning system, which can be controlled in many ways, you have to install a lot of light switches. This relates to bigger cable consumption. With wireless components this can be avoided. Wire savings in lightning come mainly from the area between light switch and lamp. However, you need also receivers to the same functions, which you do with normal switches. These components you do not need in ordinary installation.

In this model house wire savings between wireless and wired come from two different sections: the connection between the light switch and the lamp or the connection between the motion-sensor and outdoor lightning. The differences can be found on TABLE 3.

Target	**Length (m)**
Light switches 1.5 mm2	174
Wire between lights 1.5 mm2	272
The electrical connection 1.5 mm2	263
Outdoor lightning 2.5 mm2	154
Outdoor lightning, motion-sensor connection 2.5 mm2	41
Total	**863**
Lightning with wireless components	648

TABLE 3 Cable length in lightning layout.

On appendixes 6 and 7 you can see the layout with standard wired installations and on appendixes 8 and 9 electrical plan with wireless devices. The only difference is that the connection between lights and switches or motion-sensors has disappeared and also receivers have been installed to the ceiling. The letter “R” near the lights in the layout sings for receiver. Components, which are included to this layout, can be found on TABLE 4.

Components	**Pcs**
Light switches	25
(Receiver)	22
Lights	43
Outdoor lights	8
Fluorescent Bulb	5
Motion-sensor	3

TABLE 4 Components used in lightning layout.

7.2 HVAC designs

With a diverse HVAC system you could link window sensors in every window and door. This particular model house has 13 points (window or door), where you can mount the sensor. This of course saves a lot of copper wire compared to standard wired system. Anyhow, we do not calculate these window sensors in this work, because they are not so frequently used in Finland.

Another important issue is the heating system of a house. Nowadays under floor heating is the most common way. There are two possibilities to do this, the more general version in Finland is the thermal wires, heated with electricity and not so popular, and also bit more expensive to build, is the water heating.

In both heating versions you can save wire by using wireless thermostats. And also you save copper, when you do not need to install thermal wire in ground. If you use electrical floor heating, you do not save that much copper compared to water heating.
There are four options to choose from:

1. heating with water and wireless room sensor
2. heating with water and wired room sensor
3. heating with electricity and wireless room sensor
4. heating with electricity and wired room sensor

Thermostats, which I used in wired installations, were Ensto ECO10FE double action thermostat with air temperature sensor and thermal element sensor installed in the middle of the floor. Every floor sensor was equipped with 4m 2x0.53 mm^2 copper wire.

Wireless thermostats measure only room air temperature and send the signal to the receiver, which is situated near the main centre for electrics or near the boiler. In case you use water heating. I chose to install two thermostats in the larger rooms (BR1, LR, Lounge and BR5), because there might be disorders, if the room is large enough and the temperature is measured only at one point. Usually they are installed near the door, which might be open in many cases and might make measuring unreliable. The wire savings on these four different options can be found on TABLE 5.

Underfloor heating alternatives	Wire length 2.5mm^2 (m)	Wire length 0.53 mm^2 (m)	Heating cable length (m)
Thermowire heating with wired thermostat	519	112	780
Thermowire heating with wireless thermostat	315	0	780
Water flow heating with wired thermostat	407	112	0
Water flow heating with wireless thermostat		0	0

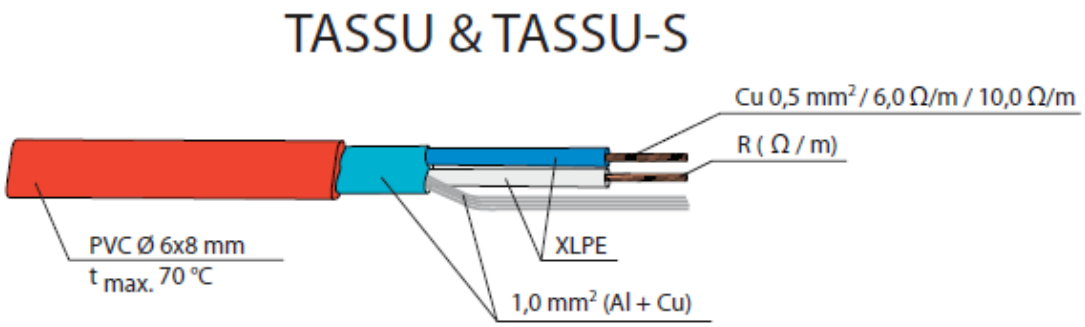
TABLE 5 Different floor heating alternatives.

The model I use in battery powered model was Horstmann HRT4-ZW-TX Z-Wave thermostat PICTURE 7. Finnish company called Smarthome is specialized to these Z-Wave products. And in energy harvesting model I chose to use Peha Easyclick room temperature sensor with solar energy storage20.450.xx FU-RTR PICTURE 8.

PICTURE 7 Horstmann HRT4-ZW Z-Wave thermostat. (www.smarthome.fi)

PICTURE 8 Peha Easyclick EnOcean thermostat. (www.greenelectric.eu))

Approximate heating calculations I did with CADS Planner and based on that (appendixes 10 and 11) I chose equivalent heating cables from the Ensto manufacturer product range. Structural view of the Ensto Tassu heating cable found on PICTURE 9. Room specific information can be found on TABLE 6



PICTURE 9 Ensto Tassu heating cable.
(http://products.ensto.com/documents/ii/heat/Tassu_TassuS_RAK08_UM2.pdf)

Room	Area (m^2)	Type	Length (m)	Power (W)
1st floor	**111.5**		**539**	
BR1	15	TASSU16	72	1600
BR2	9	TASSU12	54	1200
BR3	9	TASSU12	54	1200
BR4	12.4	TASSU16	72	1600
WR+S	7.5	TASSU6	29	600
UR	7.7	TASSU6	29	600
KITCHEN	15	TASSU12	54	1200
ENTRY	4.3	TASSU3	15	300
VESTIBULE+WC	11.1	TASSU12	54	1200
LR	20.5	TASSU22	106	2200
2nd floor	**54.1**		**241**	
BR5+WIC1	19.2	TASSU18	86	1800
LOBBY+WIC2	18	TASSU18	86	1800
WC	3.5	TASSU3	15	300
BR6	13.4	TASSU12	54	1200
Total	**165.6**		**780**	**16800**

TABLE 6 Room specific heating cables

8 Calculations

These calculations show, how energy efficient wireless automation can be. The majority of CO_2 emission comes from cables and cable ways, used in building. In the end we compare price of different installation methods and estimate, what maintenance costs will be in future.

8.1 Copper

According to the copper life cycle assessment PICTURE 6 shows that 1.0 mm^2 copper wire produces 0.0378 kg CO_2-equiv/m. With the cable length given by CADS on this model house we can calculate the CO_2 emissions in lightning. On wireless model we reduce the wires used in the light switches and the wires between the motion-sensor and the light. Calculations found on TABLE 7.

Target	Length (m)	CO_2 (kg)
Light switches 1.5 mm2	174	9.84312
Wire between lights 1.5 mm2	272	15.40539
The electrical connection 1.5 mm2	263	14.93478
Outdoor lightning 2.5 mm2	154	14.54355
Outdoor lightning IR connection 2.5 mm2	41	3.8934
Total	863	58.62024
Lightning with wireless components	648	44.88372

TABLE 7 Lightning cable length and CO^2 emissions.

As we can see on TABLE 8 the chosen heating option saves or consumes lots of copper wire depending on what type of heating is used. The compound Al/Cu used in the heating cable (PICTURE 7) I did not find, so I assume it to be 50/50 between these two materials.

Under floor heating alternatives	Mains connection wire length 2.5mm^2 (m)	Thermostat wire length 0.53mm^2 (m)	Heating cable length (m)	CO_2 (kg)
Thermo wire heating with wired thermostat	519	112	780	95.47
Thermo wire heating with wireless thermostat	315	0	780	73.96
Water flow heating with wired thermostat	407	112	0	40.66
Water flow heating with wireless thermostat	0	0	0	0

TABLE 8 Cable using and CO^2 emissions in heating.

8.2 Plastic

Most of the plastic comes from the insulation plastic on wires and from the plastic on cable ways. Plastic (PVC) on wires can be calculated with the information found on Draka manufacturer white paper. ML 1.5 mm^2 wire diameter is 2.8 mm. (Wire information white paper Draka)

From there we can calculate plastic weight on one meter:

Wire outer diameter d=2.8 mm

Wire radius can be calculated with the formula 1:

$$r = \frac{d}{2} \quad (1)$$

$r = \frac{2.8}{2} = 1.4$ mm

Total wire surface with the formula 2:

$$A = \pi * r^2 \quad (2)$$

$A = \pi * 1.4^2 = 6{,}158\ \text{mm}^2$

Plastic area: $6.158\ \text{mm}^2 - 1.5\text{mm}^2 = 4.658\ \text{mm}^2$

Plastic volume 1 m wire: 1 m*0.000004658= 0.000004658 m^3

Density of PVC: 1.4 g/cm^3 =1400000 g/m^3 (PVC density PVC.org)

1.5 ML total plastic weight per meter: $1400000\text{g/m}^3 * 0.000004658\ \text{g/m}^3 = 6.521$ g (rounded to 3 decimal)

With the same method we can calculate plastic weight to the 2.5 mm^2 wire:
2.5 ML Draka wire diameter is 3.4 mm. So 2.5 ML total plastic weight per meter is 9.211 g (rounded to 3 decimal)

Thermostat wire length was 4 m and the diameter on its cable is 7.5 mm. There is 2x.0.53 mm^2 copper wire inside of the insulation plastic. Total plastic weight is 60.367 g/m rounded to 3 decimal. Results on insulation plastic are shown on TABLE 9.

8.2.1 Plastic from PVC pipe

These wire installations were mainly made by ML wire, so the wires need to be installed in the M20 PVC pipes. From CADS I can get the information about this also. Needed pipe length varies on what electrical layout you use. Total usage of PCV plastic and CO_2 emission is shown at TABLE 9.

According to PlasticEuropa the CO_2 emissions for PVC is 6.0 kg/kg. The pipe model what I used was Pipelife JM 20 and the weight for 1 m is 0.115 kg. (Product catalog SLO)

	PVC plastic pipe (m)	PVC pipe weight (kg)	PVC on cable insulation (kg)	CO_2 (kg)
Lightning				
Standard wired	310.3	35.7	6.4	252.6
Wireless	215.9	24.8	4.9	178.4
Heating				
Thermowire heating with wired thermostat	175.1	20.1	11.5	190.0
Thermowire heating with wireless thermostat	88.4	10.2	2.9	78.4
Water flow heating with wired thermostat	119.1	13.7	10.5	145.2
Water flow heating with wireless thermostat	0.0	0.0	0.0	0.0

TABLE 9 Plastic emissions on different models.

8.3 Battery

The batteries used in this Z-Wave model were Li-ion and NiMH. On Schneider Electrics connect system we used Energizer CR 2450 Li-ion coin cell battery. To the room thermostats we chose Duracell DX2400 NiMH 800 mAh HR3 rechargeable "stay-charged" model. And to compare the difference I chose Energizer Ultimate Lithium non-chargeable. The CO_2 emissions caused by the battery can be found on TABLE 10.

Overall this model consumes 25 coin cell batteries to 25 light switches and 36 AAA batteries to the 18 thermostats. According to Schneider, average life cycle for coin cell battery was 7-10 years. And Horstmann gives two year battery life on their thermostats. Effect of time to battery consumption and CO_2 emission is shown in TABLE 11.

	Pcs	**Battery weight (kg)**	**CO_2 emissions (kg/kg)**	**CO_2 (kg)**
Lightning				
Energizer CR 2450 (Li-ion battery)	25	0.0068	12.500	**2.125**
Heating				
Duracell AAA (NiMH battery)	36	0.0128	13.600	**6.267**
Energizer AAA (Li-ion battery)	36	0.0076	12.500	**3.721**

TABLE 10 Battery CO_2 emissions between different battery types.

Life cycle (years)	**0**	**5**	**10**	**15**	**20**	**25**	**30**
Total CO_2 with CR2450 change	2.125	2.125	4.250	6.375	6.375	8.500	10.625
Total CO_2 with CR2450 and rechargeable NiMH AAA battery	8.392	8.392	10.517	12.642	12.642	14.767	16.892
Total CO_2 with CR2450 and Li-ion AAA battery	5.846	12.385	24.770	33.735	43.995	52.960	65.345

TABLE 11 Battery life cycle effect.

8.4 The price of installation

Wireless automation is usually used when renovating. The price of the wireless components is higher compared to normal wired components, however hiring an electrician is expensive also. With wireless devices you save time, because of you do not need to demolish walls and install new wires. We will look next into savings of time and money, which could be achieved, if you choose right components for your purpose.

8.4.1 How expensive wireless technology is

Wireless devices are clearly more expensive than the normal wired ones. One important matter is, that wireless is a new thing in Finland. That is why markets are quite small and prices are high. Price comparison with most frequently used components can be found in TABLE 12, 13 and 14.

The prices in the tables consist of different suppliers in Finland or internet stores. There was not any company, which would sell all these products. In wired and Z-Wave model the prices are gathered from Finnish internet stores called taloon.com and smarthome.fi. And in energy harvesting model the prices are gathered from internet store greenelectric.eu. It has specialized on EnOcean products and its member of EnOcean Alliance.

Target	Manufacturer/type	Length (m)	Price (€)	Pcs
1.5 ML wire	Draka	709	66.5/200 m	4
2.5 ML wire	Draka	671	109/200 m	4
PVC pipe	PipeLife	626	1.35/2.5 m	251
1-switch	ABB Jussi		6.29	6
5-switch	ABB Jussi		9.39	2
7-switch	ABB Jussi		15.5	2
Dimmer	ABB Jussi		83.9	8
Dual dimmer	ABB Jussi		149	7
Cover plate 1 gadget	ABB Jussi		2.25	19
Cover plate 3 gadget	ABB Jussi		5.09	3
Thermostat	Ensto ECO10FE		72.5	14
Motion sensor	ABB Jussi Vahti 280		189	3
Total			**4482.59**	

TABLE 12 Standard wired layout item prices

Target	Manufacturer/type	Length (m)	Price (€)	Pcs
1.5 ML wire	Draka	535	66.5/200 m	3
2.5 ML wire	Draka	154	109/200 m	1
PVC pipe	PipeLife	306	1.35/2.5 m	123
1-switch	Schneider connect		72.13	16
5-switch	Schneider connect		76.46	9
Receiver	Schneider connect		88	10
Receiver dimmable	Schneider connect		125	12
Thermostat and receiver	Horstmann HRT4-ZW		145	18
Motion sensor	Merten Argus 220 Connect		155.72	3
CR2450 coin battery	Energizer 1 pc/packet		2.36	25
AAA li-ion battery	Energizer 4 pcs/packet		8	9
Total			**7904.93**	

TABLE 13 Z-Wave layout item prices.

Target	Manufacturer/type	Length (m)	Price (€)	Pcs
1.5 ML wire	Draka	535	66.5/200 m	3
2.5 ML wire	Draka	154	109/200 m	1
PVC pipe	PipeLife	306	1.35/2.5 m	123
1-switch	Peha Easyclick		48.8	16
5-switch	Peha Easyclick		48.8	9
Receiver	Peha Easyclick		73	10
Receiver dimmable	Peha Easyclick		94	12
Thermostat	Peha 20.450.02 FU-RTR		179	18
Thermostat receiver	Peha 451 FU-E RTR		169	14
Motion sensor	Echoflex MOS-17C		0	3
Total			**9140.55**	

TABLE 14 Energy harvesting wireless model item prices.

Time effect from the first 30 years is shown on TABLE 15. In Z-Wave model there has been taken into account two battery options. FIGURE 2 shows us effect of batteries compared to models without it. It is assumed, that the CR2450 battery is being replaced by new one every 7th year and the AAA battery is changed or recharged every 2nd depending on used battery type.

System	Price (€)	Price (€)	Price (€)	Price (€)	Price (€)	Price (€)	Price (€)
Standard	4482.59	4482.59	4482.59	4482.59	4482.59	4482.59	4482.59
EnOcean	9140.55	9140.55	9140.55	9140.55	9140.55	9140.55	9140.55
Z-Wave with li-ion batteries	7904.93	8179.93	8454.93	8657.93	8873.93	9076.93	9351.93
Z-Wave with li-ion and NiMH batteries	7981.51	7981.51	8040.51	8099.51	8099.51	8158.51	8217.51
Years	0	5	10	15	20	25	30

TABLE 15 Price comparison between different building techniques.

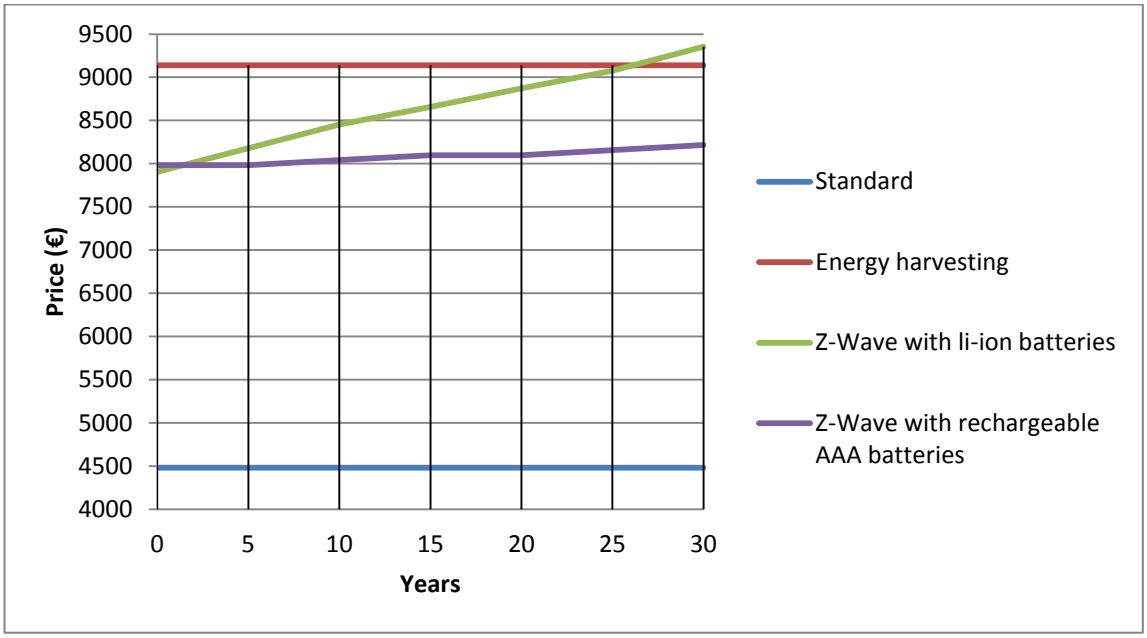


FIGURE 2 Price comparison between different building techniques

8.5 Life cycle assessment

In this case I chose to use water heating as the primary heating option. This way we can get more reliable results, when comparing the wired and non-wired options. The life cycle of this installation is 30 years. TABLE 16 shows the difference between these three systems after construction.

Design model	Copper CO_2 (kg)	Plastic CO_2 (kg)	Battery CO_2 (kg)	Total CO_2 (kg)
Standard lightning & water heated floor	99.28	397.83	0	497.10
Z-Wave with water heated floor with CR2450 and re-chargeable NiMH AAA battery	44.88	178.41	8.39	231.68
Z-Wave with water heated floor with CR2450 and li-ion AAA battery	44.88	178.41	5.85	229.14
Energy harvesting (EnOcean)	44.88	178.41	0	223.29

TABLE 16 CO_2 emissions after construction.

Life cycle from the first 30 years is shown on TABLE 17 and FIGURE 3 shows us effect of batteries compared to models without it. It is assumed, that the CR2450 battery is being replaced by new one every 7th year and the AAA battery is changed or recharged every 2nd depending on the used battery type.

	CO_2 (kg)	CO_2 (kg)	CO_2 (kg)	CO_2 (kg)	CO_2 (kg)	CO_2 (kg)	CO_2 (kg)
Standard	497.10	497.10	497.10	497.10	497.10	497.10	497.10
Z-Wave with li-ion batteries	231.68	240.07	242.20	244.32	244.32	246.45	248.57
Z-Wave with li-ion and NiMH batteries	229.14	241.52	253.91	262.87	273.13	282.10	294.48
EnOcean	223.29	223.29	223.29	223.29	223.29	223.29	223.29
Years	0	5	10	15	20	25	30

TABLE 17 life cycle with different construction methods.

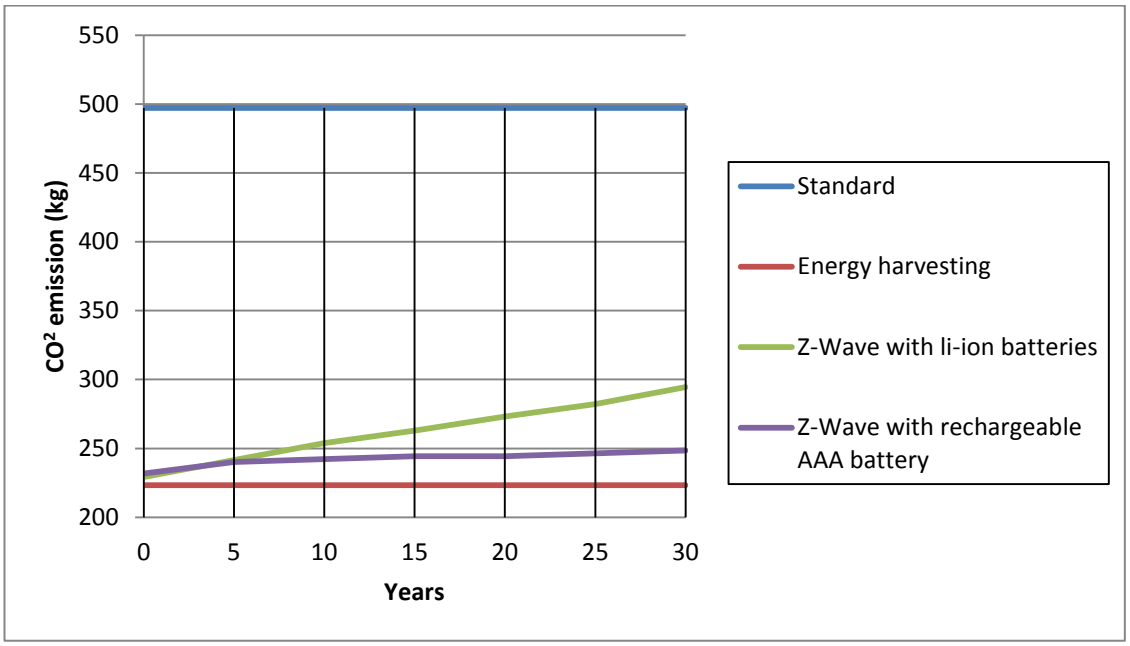


FIGURE 3 Life cycle with different systems.

9 DISCUSSION

As a conclusion we can state, that wireless technology is more ecological compared to standard house electricity. How much benefit it will offer, it depends on what kind of products you decide to use. As was shown, all functions could not be carried out with wireless devices. But the technology is coming more popular and cheaper and in that way more accessible to ordinary households.

One important factor when thinking, what kind of equipment should be used, is the time saving, which comes with wireless devices. As we can see, saving in between the light switches and the lights include quite a lot of wire raw materials and work time. The installation of the wireless switch is easy and there is only the programming of the devices after installation. The programming methods vary with different systems, but usually it is easy and fast to do.

9.1 Price

Price of cables is not correct, because of size of the packet. There are different needs of different colors for e.g. brown, blue and green-yellow are the most common colors. But also black and grey colored wires are needed. The problem is, that taloon.com retailer sells ML wire only 200 m packet size. It is worth of noticing, that this layout did not include the electrification to sockets and other equipment. In these you will also need these same wires, therefore the left over wires can be used in these installations.

The energy harvesting motion-sensor Echloflex MOS 17 was not available in any retailer by internet. Other energy harvesting motion-sensors were not designed to be used outdoors. Even optimal operation temperature of this model was announced to be between 0-30 ˚C, which indicates, that this probably will not work properly in Finnish environment.

Wireless room sensors and the receivers were a bit of a question mark. This model case shows, that when using Z-Wave and EnOcean products, you need to buy quite many receivers to control different heating areas separately. Horstmann HRT4-ZW thermostat and receiver were included in the same price of 145 €. But when using Peha devices you

have to buy 14 receivers in addition to 18 thermostats. This will raise the total price of installation considerably.

The price of installation stays same in standard and EH model assuming, that no device breaks. In a battery powered model you have to replace batteries, used in thermostat and light switches. For these devices, which I used, you do not need to hire an electrician to change battery, because they work only with small power.

As seen on TABLE 16 clearly the cheapest way to install devices is the standard wired version. Difference between Energy harvesting and battery powered type is also significant. And as it was shown, the effect of what type of batteries you use, comes more important as time goes by. One thing, which should be taken into account is, that the price of batteries might vary in future and how these calculations can be changed. Even though wireless technology is more expensive, it should be taken into account, that there is also noticeable saving in working hours, at least when we are speaking renovation of an old house. Demolition and rebuilding of walls take a long time and this step could be avoided when installing wireless transmitter (switch for e.g.) by glue to where ever you want.

Average wage of a qualified electrician in Finland is approximately 50 € /hour, including tax. This might vary depending on the location, but it is usually higher in Southern Finland than in the North.

9.2 Environmental point of view

Calculations on life cycle assessment indicate, that the biggest CO_2 producers are the PVC pipes. However, the emission produced by pipe sequels and the connection boxes, have not been calculated.

Alternative option would be installing different cable type such as MMJ. With this cable you can mount the cable without PVC pipe. The price of this cable is slightly higher than the ML, but then again you save money on mounting pipe.

Worth of noticing is also, that mounting pipe used in thermostat sensor element cable is calculated with 4 m length per one sensor. This length might be longer or shorter depending on the distance between sensor element and thermostat. Wire can be extended up to 10 m with ML 1.5 wire for e.g.

The difference between heating types has noticeable effect on emissions. The electricity warmed option consumes quite a lot of copper and also plastic in insulation. While water heated option consumes plastic pipe. Water heating is harder to mount in the floor, because it needs to be tied to the floor firmly. Anyway there are many differences between these two systems, which are hard to assess to see, which one would be more environmental friendly. One factor affecting the selection of heating is, that do you use geothermal heat, air heat or electricity for heating. Today geothermal energy has increased popularity in smaller houses and not only in bigger properties. With this heating form is it recommended, that you heat a big boiler, which heats floors also.

Components, which effect on CO_2 emissions with different installations, were not included in this work. ABB had quite precise calculations about their products raw materials, but other manufacturers did not. For this reason I did not take this to closer examination. However, it is sure, that more raw material is used in wireless layout devices, because of there is need for two components (transmitter and receiver) instead of one in standard wired model.

9.3 Cons about wireless automation

So far these wireless devices have been used on specific targets and the whole system is not fully based on that, basically because of the higher price. Usually single-family houses are based fully on standard technology, but the various incoming devices allow to use as much wireless devices as possible.

Installation must be closely monitored since the installer does not necessarily understand, why these wireless devices can not be installed between two air condition pipes, supposing they are made of metal. Also the communication distance might be shorter than brochures tells. In Stone house the transmission decays easier compared to standard wooden house.

There are prejudices with every new technology and this wireless in no exception. One thing, which might worry people, is the health aspect. Some people might think, that exposure to these radio waves is harmful. At least EnOcean has investigated this issue and has come to the conclusion, that it is perfectly safe to use these wireless devices in a private house.

9.4 What can still be done

When we think about future perspectives in this field, they look good. Almost everything in this field is open to all kind of companies and new challenges. Some of the companies such as FSM-Group just launched their first product to market in Finland.

From an environmental point of view there is quite a lot to do. When calculating these CO_2 emissions, there are many different factors you should look more closely. The calculation, which I did, were just giving the guidelines. However CO_2 fumes on electrical parts for one house is marginal compared to every other material, which is used there during the building project. I think, that the most important fact about installing automation system is, that it should be long-lasting and energy efficient.

9.5 Analysing the project

When looking at the project plan (Appendix 12) and compare to this project, you see the difference. First of all these calculations, which I did for the house, should have been done with C++ or other programming language. However, I found it quite hard, because I had only knowledge of one course of programming before this thesis. In November I gave up that plan and decided to do the modelling with CADS Planner and do these calculations with Microsoft excel.

When thinking the time line and how I used my time with this project, it went quite well. I made a logbook from every day, what I did and how many hours I worked. When you look it at the end, you can see few breaks there in the middle of the project and also that the project was delayed a little. Original plan of retuning this thesis was 14th of January, but I rescheduled it to 29th of January.

The fairly difficult part was the modelling and the research of Finnish suppliers. In the modelling part I did not find all the necessary parts from the same supplier, so I had to mix products of different manufacturers. All the interesting companies in this field did not answer to my numerous Emails. Overall, the project was a success and all problems were solved in the end of the work.

REFERENCES

Official Journal of the European Union, Commission Regulation (EC) No 244/2009. Read 17.10.2012
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:076:0003:0016:en:PDF

Bluetooth Standard. Read 21.11.2012
http://www.bluetooth.com

Bluetooth Low Energy. Read 21.11.2012
http://en.wikipedia.org/wiki/Bluetooth_low_energy

Bluetooth Special Interest Group. Read 21.11.2012
http://www.bluetooth.org/Membership/introduction.htm

Z-Wave Alliance. Read 17.10.2012
http://www.zwavealliance.org/our-history

Z-Wave Wikipedia. Read 17.09.2012
http://en.wikipedia.org/wiki/Z-Wave

ZigBee Alliance. Read 17.10.2012
http://www.zigbee.org/Home.aspx

ZigBee Alliance. Green Power white paper. Read 08.01.2013
https://docs.zigbee.org/zigbee-docs/dcn/12/docs-12-0646-01-0mwg-new-zigbee-pro-feature-green-power.pdf

X10 Wikipedia. Read 18.10.2012
http://en.wikipedia.org/wiki/X10_(industry_standard)

X10 wireless Technology. Read 18.10.2012
http://en.wikipedia.org/wiki/X10_Wireless_Technology

EnOcean technology. Read 18.10.2012
http://www.enocean.com/en/home/

EnOcean Alliance. Read 19.10.2012
http://www.enocean-alliance.org/en/home/

EnOcean White Paper, Read 12.11.2012

FSM Group homepage. Read 12.11.2012
http://www.fsm.fi/index.php?main=120

Vaasan Sähköpalvelu. Read 12.11.2012
http://www.vaasansahkopalvelu.fi/etusivu.htm

Technical importer in Finland Hedgren. Read 12.11.2012
http://www.hedengren.fi/
Electrical importer and wholesaler in Finland Hedtec. Read 12.11.2012
http://www.hedtec.fi/
Energy certificate environment. Read 13.11.2012
http://www.ymparisto.fi/default.asp?node=14529&lan=fi
Energy certificate and statement. Read 13.11.2012
http://www.energiatehokaskoti.fi/
Energy certificate guide Ministry of the Environment. Read 13.11.2012
http://www.ymparisto.fi/download.asp?contentid=105735&lan=fi
Smart-House Carlo Gavazzi. Read 12.11.2012
http://smart-house.fi/
Company information Carlo Gavazzi. Read 11.11.2012
http://www.carlogavazzi.com/en/
Smart-House Emails Joonas Silaste (Carlo Gavazzi). Read 14.11.2012
Hedtec Lightning. Email Matti Kaitamaa. Read 15.11.2012
Company information Schneider Electric. Read 19.11.2012
http://www.schneider-electric.com
CONNECT wireless radio system Schneider Electric. Read 10.10.2012
http://www2.schneider-electric.com/sites/corporate/en/products-services/installation-systems-and-control/
Schneider Electric Email. Kalevi Härkönen. Read 19.09.2012
Product info Nexa. Read 23.11.2012 http://www.nexa.se/Home.html
Helsinginuutiset. *Increase of metal theft.* Article Read 05.12.2012
http://www.helsinginuutiset.fi/artikkeli/116529-kuparivarkaudet-kasvussa-syylliset-suomalaisia
Copper price Metalprices. Read 05.12.2012
http://www.metalprices.com/metal/copper
Battery product datasheet, Energizer. Whitepaper read 07.12.2012
http://data.energizer.com/PDFs/cr2450.pdf
Battery Life cycle analysis Argonne Research. Read 07.12.2012
http://www.transportation.anl.gov/pdfs/B/644.PDF

Cable information Draka white paper. Read 11.01.2013
http://www.draka.fi/draka/Countries/Draka_Finland/Languages/suomi/navigaatio/Tuotteet/Kiinteistoverkot/Asennus-_ja_kumikaapelit/Asennuskaapelit/ML_750V_3203a_08_D11.pdf
Mounting pipe PipeLife. Product catalog SLO Read. 20.01.2013
http://www.slo.fi/www/fi/Tuotteet/Tuoteluettelo
Retailer, internet shop Taloon Read. 20.01.2013
http://www.taloon.com/
Retailer, internet shop smarthouse. Read 20.01.2013
http://smarthome.fi/fi/
Retailer, internet shop. Greenelectric. Read 20.01.2013
http://www.greenelectric.eu/EnOcean-Technology-Shop

APPENDICES

Appendix 1. Typical Indoor Brightness Levels (Lux)

Illumination Area	Type Destination / Workspace	Typical Brightness
Home	Usually	100 – 500 lx
Schools	Corridor	100 – 300 lx
	Classroom in general	300 – 750 lx
	Reading room, laboratory	500 – 1500 lx
Offices	PC room, working at PC	200 – 500 lx
	Meeting room	300 – 700 lx
	Canteen	150 – 300 lx
	Corridors	50 – 100 lx
	Reception	300 – 700 lx
	Restroom	100 – 300 lx
Factories	Production hall	500 – 1500 lx
	Development, office	300 – 750 lx
	Design CAD	500 – 1500 lx
	Laboratory, inspection work	750 – 1500 lx
	Packaging of products	150 – 500 lx
	Storage	100 – 300 lx
Hospitals	Visitor room	300 – 500 lx
	First aid, surgery	500 – 1500 lx
	Bedroom	100 – 300 lx
	Pharmacies	500 – 1000 lx
	Wash rooms	150 – 300 lx
Hotels	Reception	200 – 500 lx
	Entrance area	100 – 300 lx
	Restaurant	150 – 300 lx
	Restroom	100 – 300 lx
	Bars	50 – 150 lx
	Corridors	50 – 100 lx
	Staircases	50 – 150 lx
Stores	Saleroom	300 – 1000 lx
	Show room	500 – 1500 lx
	Packaging area	200 – 300 lx
	Lounge	300 – 500 lx
	Conference room	300 – 700 lx
Trade Show	Booth	300 – 500 lx
Sports Arena	Indoor area	200 – 500 lx

Tab. 1: Typical Indoor Brightness Levels (Lux)

Appendices are numbered consecutively in the order they are referred to in the text. The appendices must have a title and reference if not constructed by the author. White paper (http://www.enocean.com/en/solar-energy-harvesting/)

Appendix 2. Energy certificate

ENERGIATODISTUS

Rakennus

Rakennustyyppi: Erillinen pientalo
Osoite: Kotikatu 1, 00100 Helsinki
Valmistumisvuosi:
Rakennustunnus: 427-403-2-17 D 001
Asuntojen lukumäärä: 1

Energiatodistus perustuu laskennalliseen kulutukseen ja on annettu

[x] rakennuslupamenettelyn yhteydessä
[ ] erillisen tarkastuksen yhteydessä

ET-luku	*Vähän kuluttava*	Rakennuksen ET-luokka
- 150	A	
151 - 170	B	
171 - 190	C	
191 - 230	D	D
231 - 270	E	
271 - 320	F	
321 -	G	
	Paljon kuluttava	

Rakennuksen energiatehokkuusluku (ET-luku, kWh/brm²/vuosi): 222

Energiatehokkuusluvun luokitteluasteikko: Pienet asuinrakennukset

Energiatehokkuusluokitus perustuu rakennuksen laskennalliseen energiankulutukseen.
Todellinen kulutus riippuu rakennuksen sijainnista, asukkaiden lukumäärästä ja asumistottumuksista.

Todistuksen antaja:	**Todistuksen tilaaja:**
Pekka Pääsuunnittelija	Matti Meikäläinen
Allekirjoitus: *Pekka Pääsuunnittelija*	
Todistuksen antamispäivä:	**Viimeinen voimassaolopäivä:**
23.1.2008	22.1.2018

Energiatodistus perustuu lakiin rakennusten energiatodistuksesta (487/2007) ja 19.6.2007 annettuun ympäristöministeriön asetukseen energiatodistuksesta. Tämä energiatodistus on asetuksen lomakkeen 1 mukainen.

(http://www.ymparisto.fi/download.asp?contentid=105735&lan=fi)

Appendix 3. Risk Analysis

Risk analysis

Number	Risk	Probability	Impact	Effect on project	Risk reduction actions
1	Lack of information	Medium	Medium	Calculations aren't reliable	Have to use imaginary values
2	Lack of knowledge on programming	High	High	Can't make calculations	Try to use some different calculation method
3	Technology doesn't work	Low	Medium	Can't do anything	Have to have backup files and spare computer to work with
4	Project does not stay on schedule	Medium	High	Project delay	Improve ways of working
5	Absence, illness for example	Low	Medium	Project delay	May have to work in evenings
6	Spelling and grammar	Medium	Medium	Quality of the work might look not so good	Have to spell check whole work when it is done

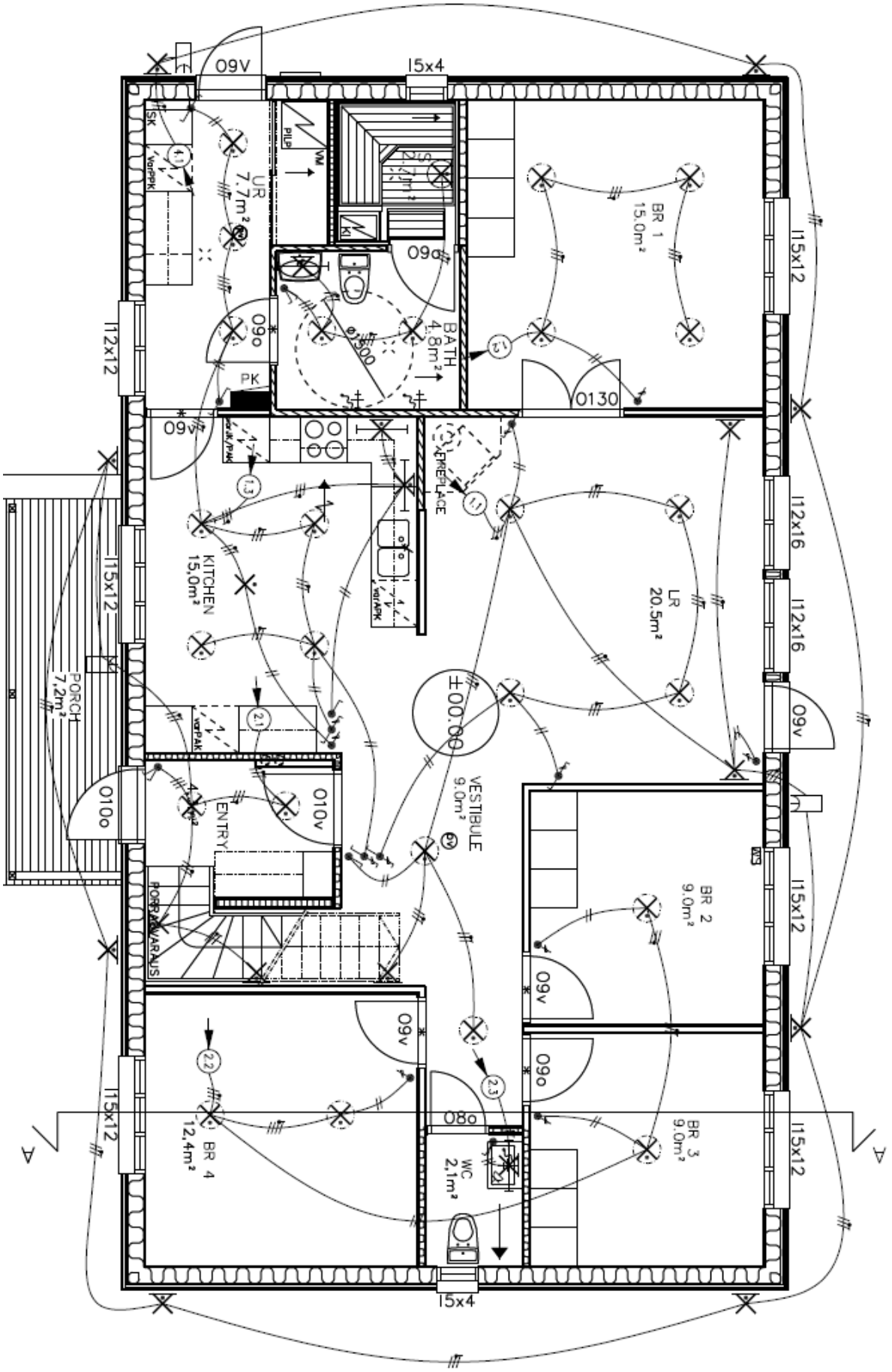
Appendix 4. Perhehelmi plain layout ground floor

(http://www.helmitalo.net/talomallisto/perhehelmi-173-118/pohjapiirros)

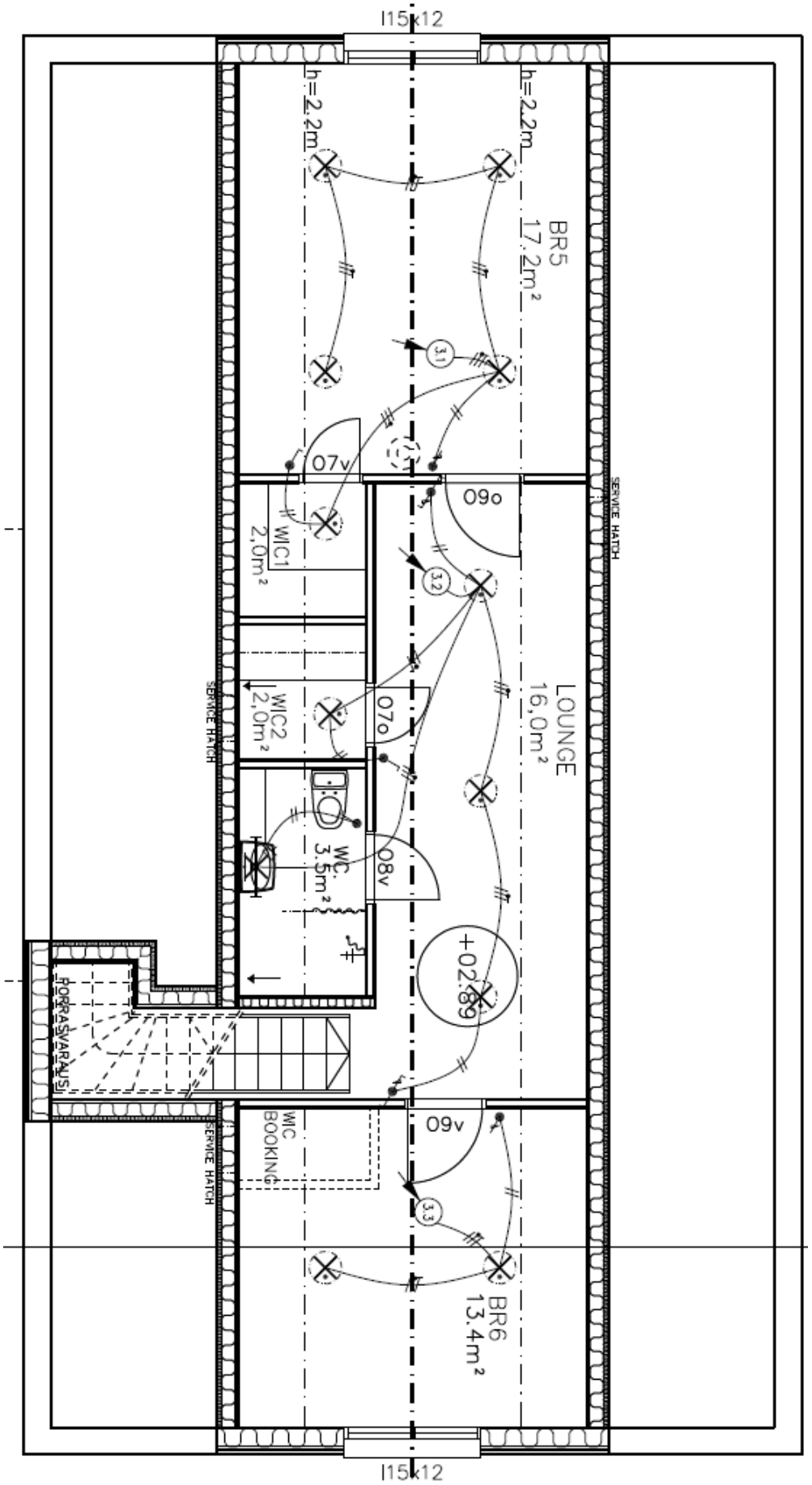
Appendix 5. Perhehelmi plain layout 2nd floor

(http://www.helmitalo.net/talomallisto/perhehelmi-173-118/pohjapiirros)

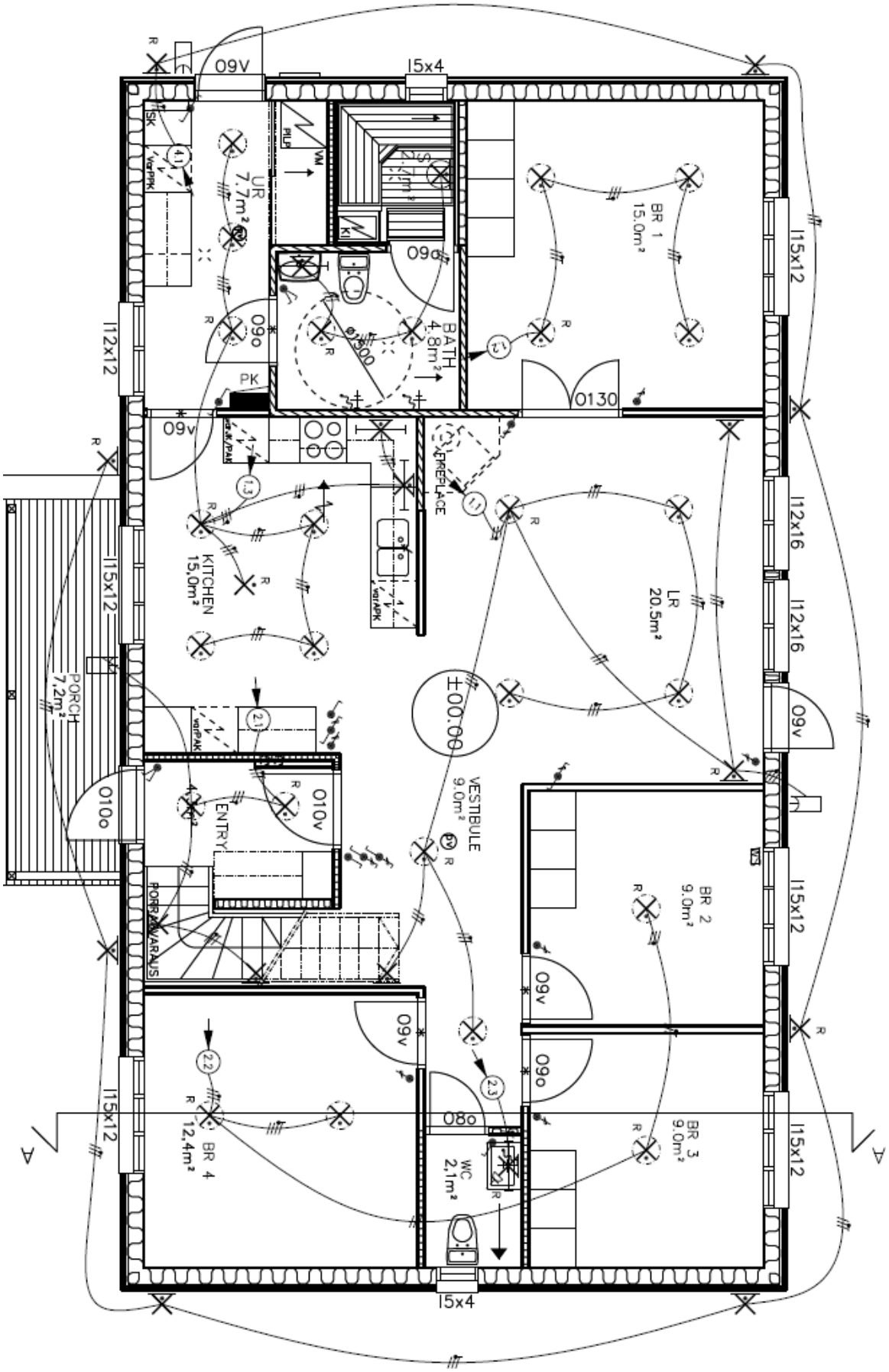
Appendix 6. Perhehelmi standard lightning layout 1st floor



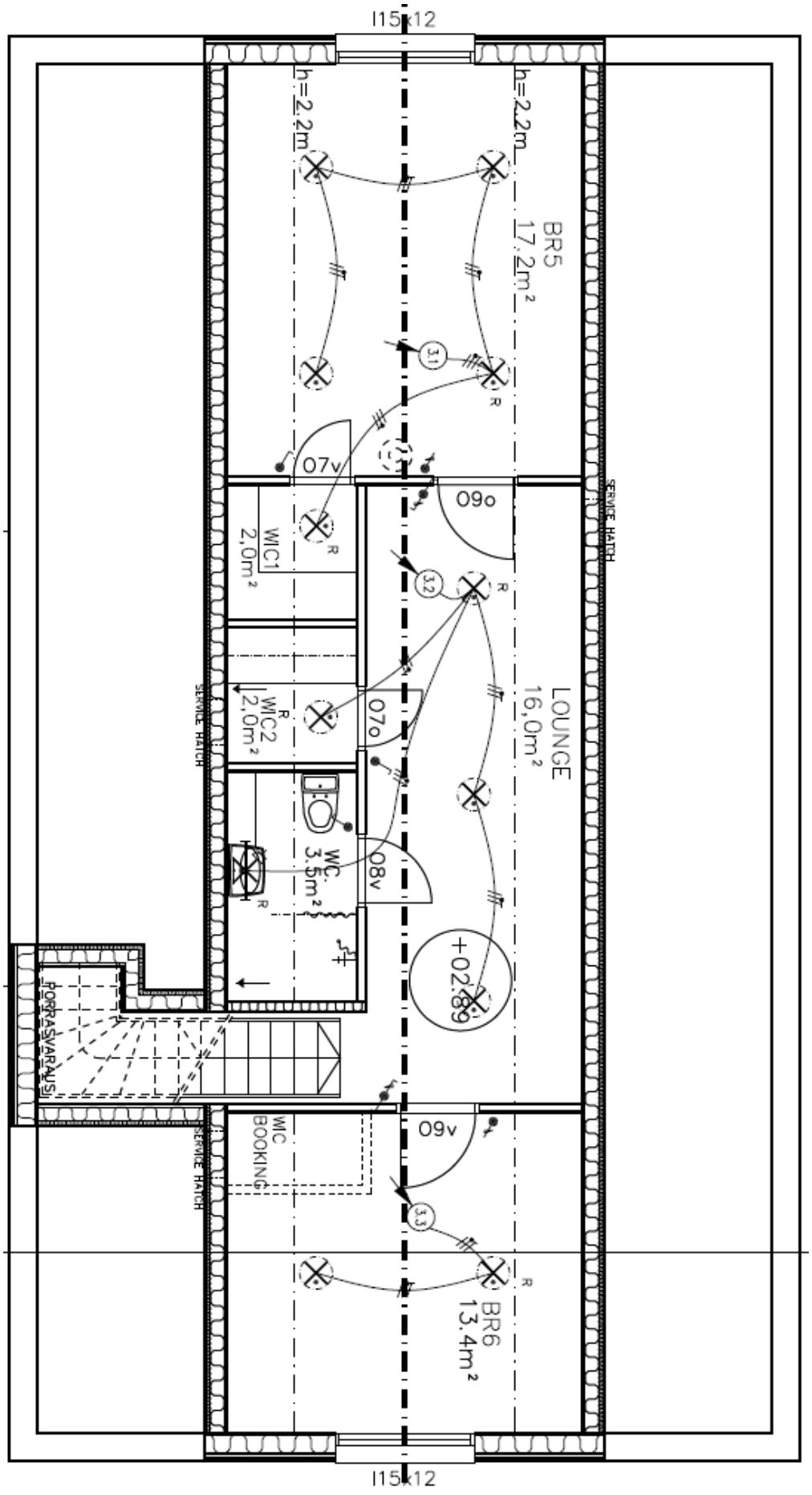
Appendix 7. Perhehelmi standard lightning layout 2nd floor



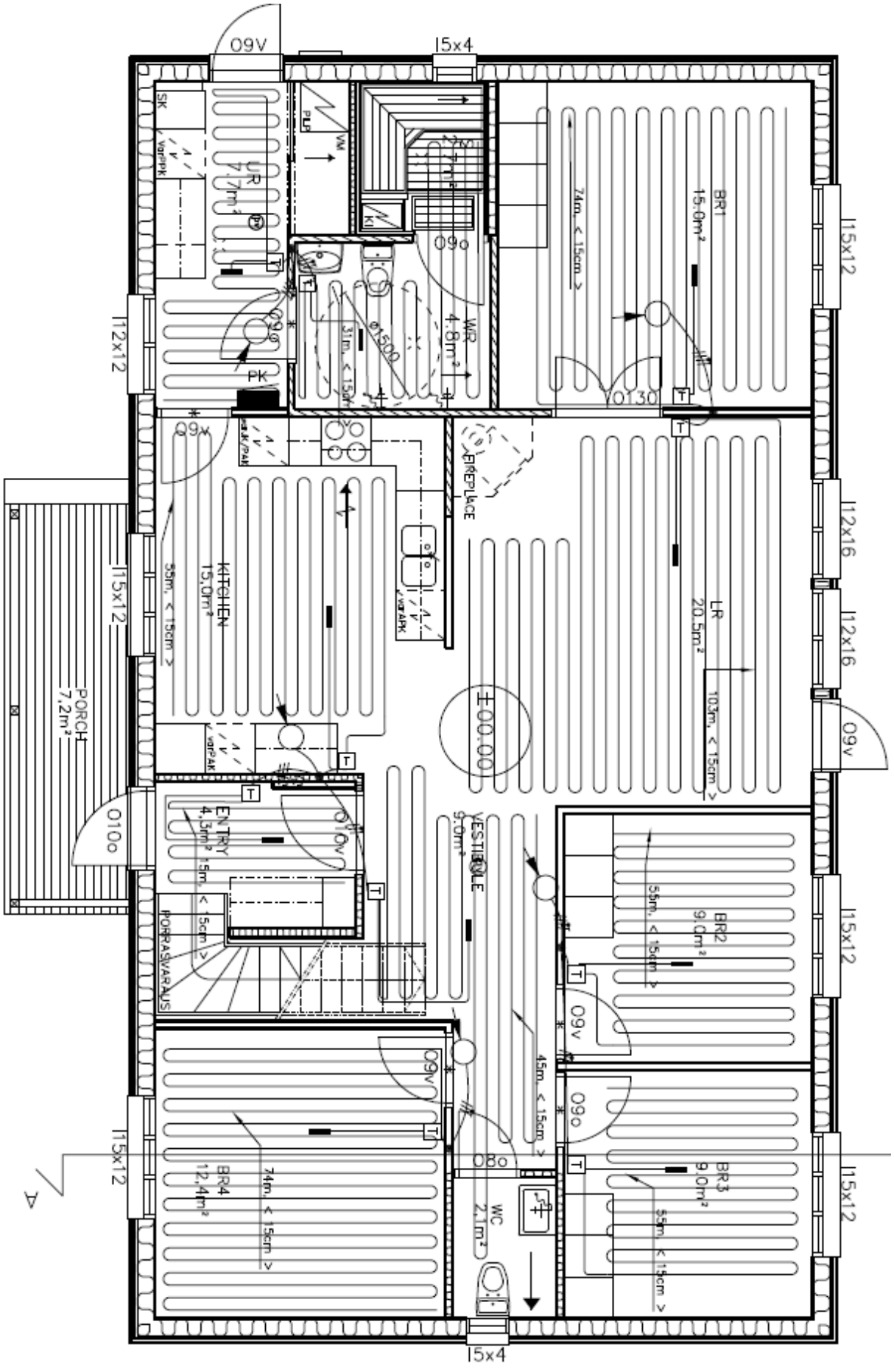
Appendix 8. Perhehelmi wireless lightning layout 1st floor



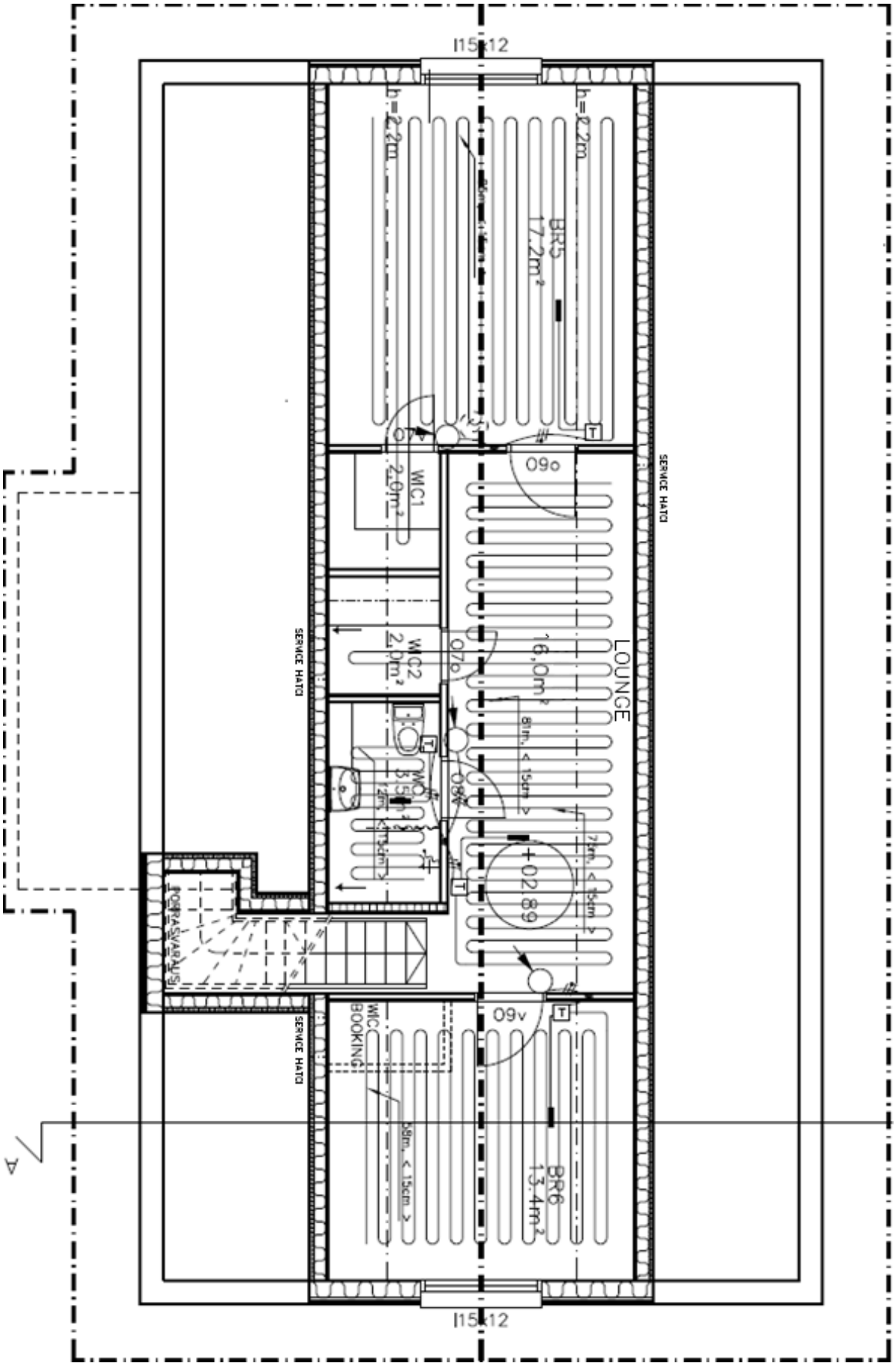
Appendix 9. Perhehelmi wireless lightning layout 2nd floor



Appendix 10. Perhehelmi heating layout 1st floor

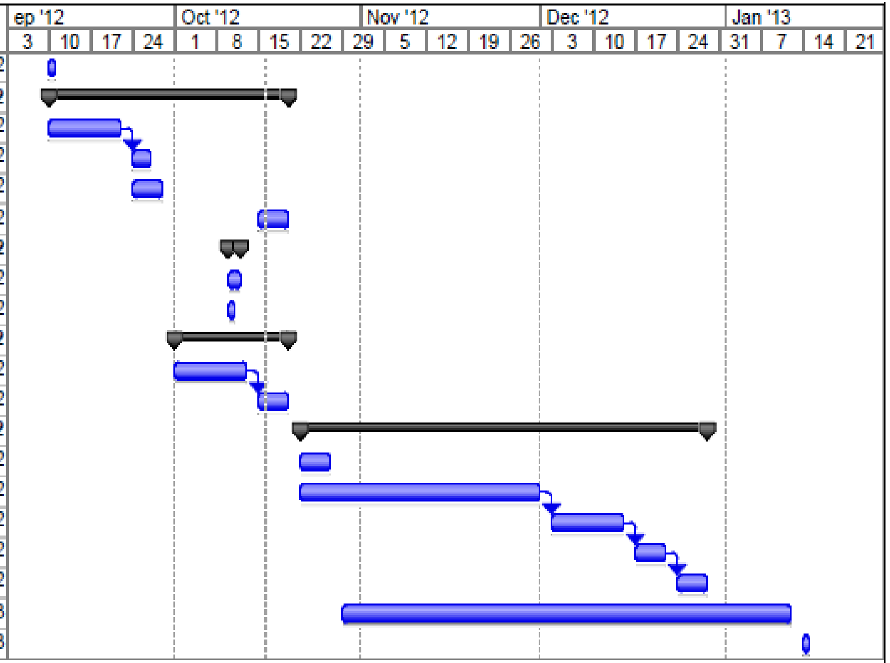


Appendix 11. Perhehelmi heating layout 2nd floor



Appendix 12. Project plan

ID	Task Name	Duration	Start	Finish
1	Start	1 day?	Mon 10.9.12	Mon 10.9.12
2	**Information gathering**	**30 days?**	**Mon 10.9.12**	**Fri 19.10.12**
3	Compare different wireless communications	10 days?	Mon 10.9.12	Fri 21.9.12
4	Learning House building automation	3 days?	Mon 24.9.12	Wed 26.9.12
5	Search Finnish building automation suppliers	5 days?	Mon 24.9.12	Fri 28.9.12
6	Look Finnish CO2 emissions	5 days?	Mon 15.10.12	Fri 19.10.12
7	**Planning**	**2 days?**	**Wed 10.10.12**	**Thu 11.10.12**
8	Project plan	2 days?	Wed 10.10.12	Thu 11.10.12
9	Risk analysis	1 day?	Wed 10.10.12	Wed 10.10.12
10	**Learning C++**	**15 days?**	**Mon 1.10.12**	**Fri 19.10.12**
11	Tutorial from Cplusplus.com	10 days?	Mon 1.10.12	Fri 12.10.12
12	Writing small programs	5 days?	Mon 15.10.12	Fri 19.10.12
13	**Modelling**	**50 days?**	**Mon 22.10.12**	**Fri 28.12.12**
14	Designing	5 days?	Mon 22.10.12	Fri 26.10.12
15	Writing code	30 days?	Mon 22.10.12	Fri 30.11.12
16	Compile	10 days?	Mon 3.12.12	Fri 14.12.12
17	Test	5 days	Mon 17.12.12	Fri 21.12.12
18	Compairing results	5 days?	Mon 24.12.12	Fri 28.12.12
19	Documentation	55 days?	Mon 29.10.12	Fri 11.1.13
20	Work delivery	1 day?	Mon 14.1.13	Mon 14.1.13



Project: Project_plan_Thesis
Date: Tue 16.10.12

Task	Milestone	External Tasks
Split	Summary	External Milestone
Progress	Project Summary	Deadline